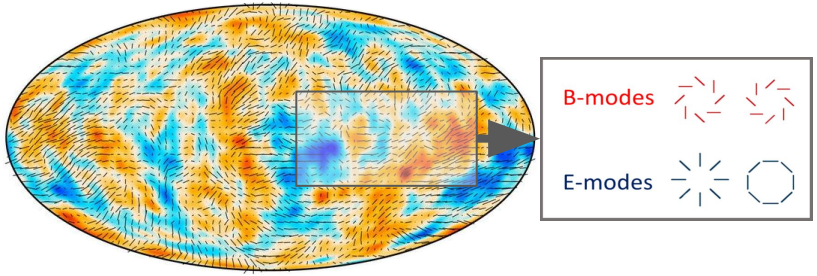
COSmological **M**icrowave **O**bservations **Cal**ibration source

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

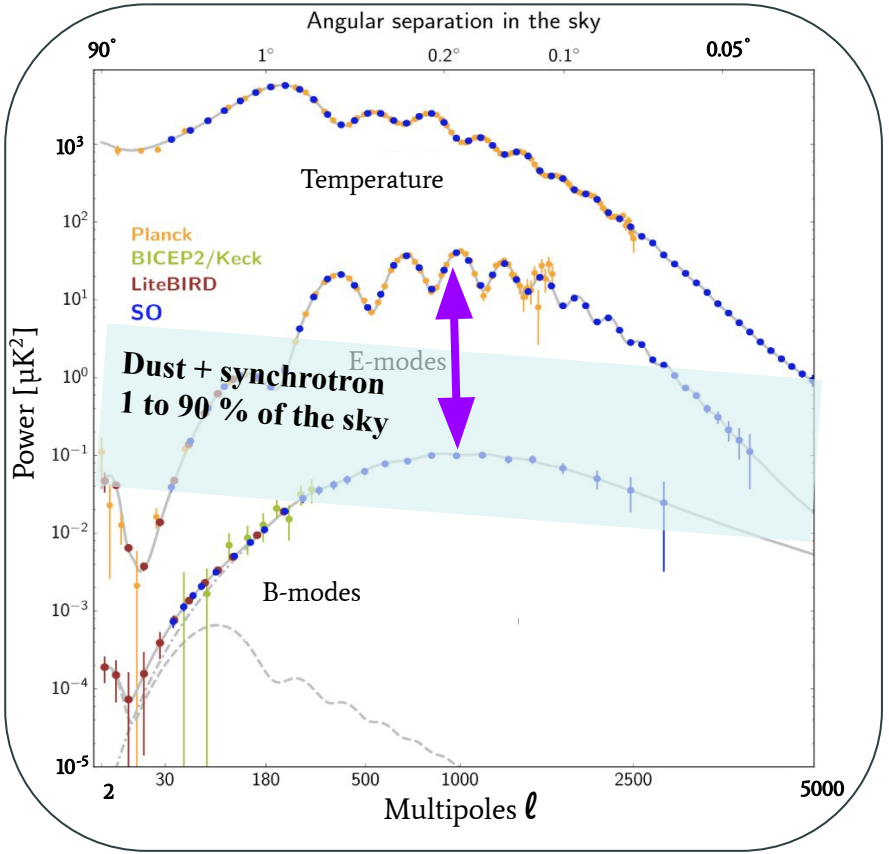


Leakage due to angle mis-calibration

Technical Challenges

- Sensitivity
- Systematics
- Calibration
- Foregrounds

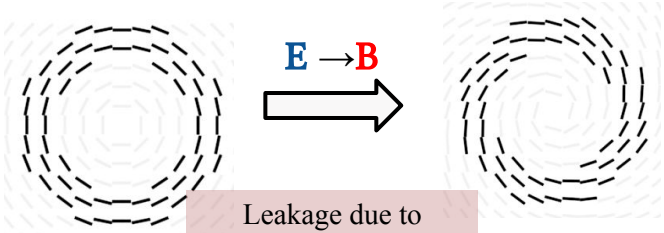
Primordial *B*-modes



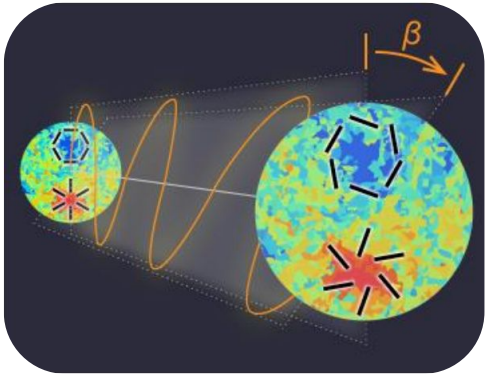
A SCIENCE CASE: the cosmic birefringence

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

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



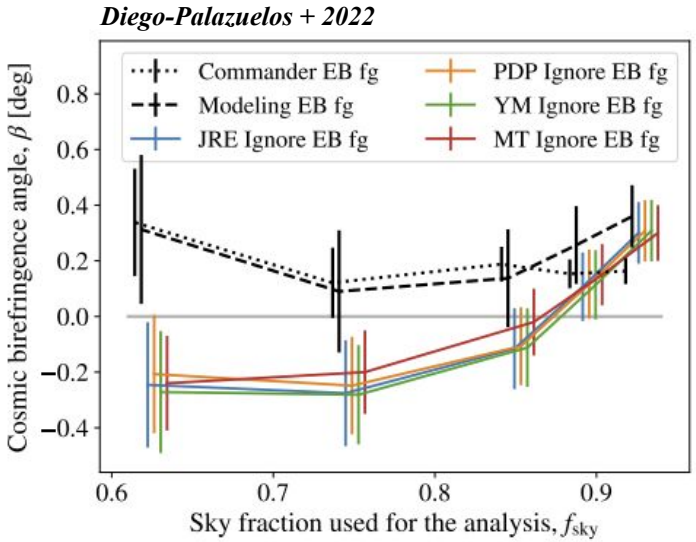
Leakage due to angle mis-calibration



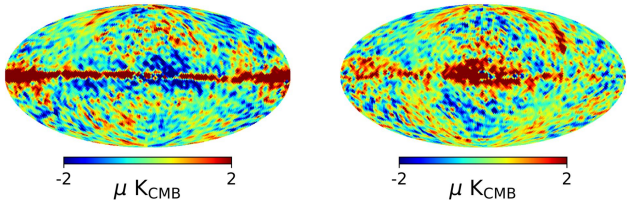
Minami, Yuto et al. 2018

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.

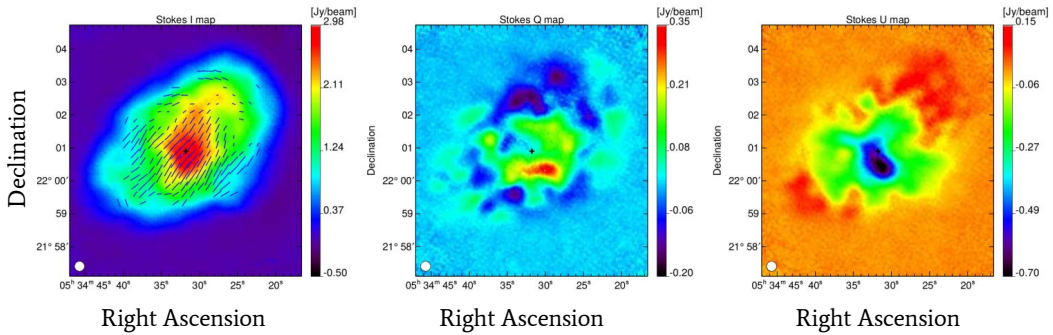
Ritacco et al. A&A, 670, A163 (2023)
Vacher et al. A&A 672, A146 (2023)

Accuracy in dust emission measurement and
absolute angle calibration is needed

1 A sky reference for calibration accuracy

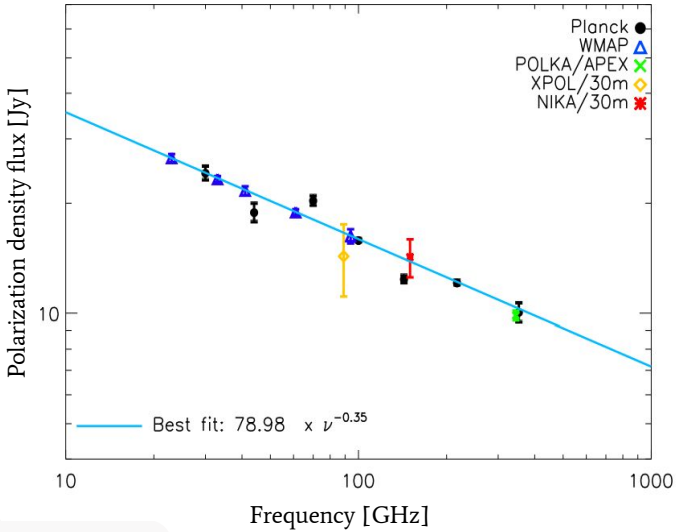
CRAB NEBULA (Tau A)

Brightest microwave extended source



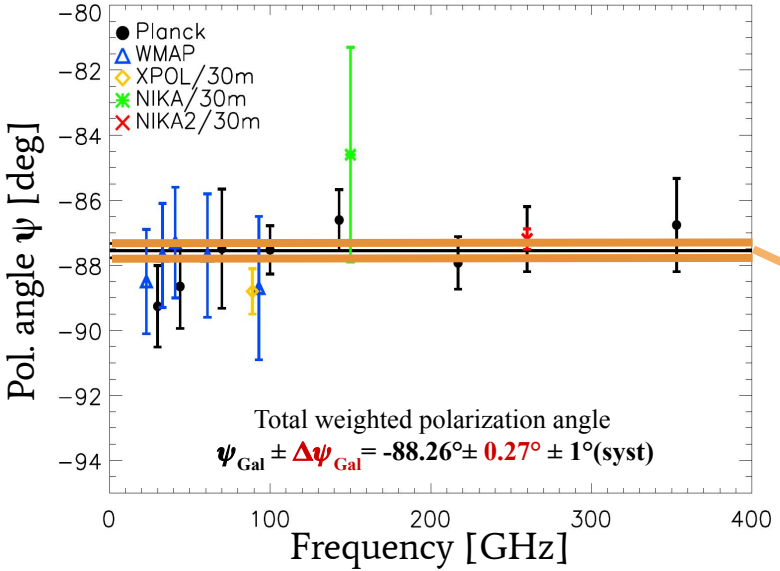
Ritacco et al. 2018 A&A, 616, A35

Polarized Spectral Energy Distribution

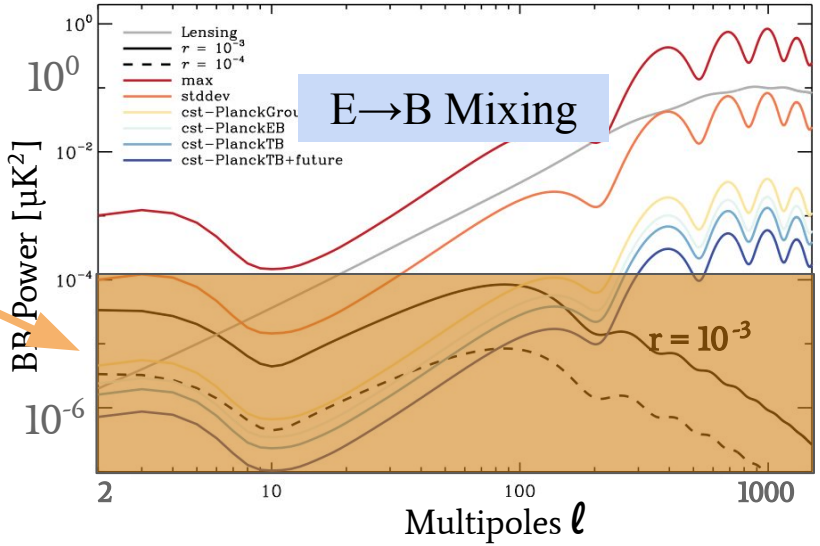


First high resolution observation at 150 GHz.
First extrapolation of the polarized SED.
Synchrotron radiation → driver of polarization.

CRAB nebula: a sky calibrator for CMB experiments



Δψ



Absolute calibration must be improved!

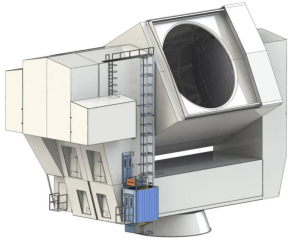
Systematics effect control:

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

Ritacco et al. 2018 A&A, 616, A35
Aumont et al. A&A 2020
Ritacco et al., EPJ WC 257, 00042 (2022)
Ritacco et al. 2025 in prep.

Absolute calibration for large aperture telescopes

GEO orbit



Simons Observatory

SRT
Sardinia Radio Telescope

iram
Institut de Radioastronomie Millimétrique

Astrophysical reference sources (e.g. Crab nebula)

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

LiteBIRD

CMB-S4
Next Generation CMB Experiment

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 **Part of S. Savorgnano's PhD work.**

2025-2026 …

Development of the space prototype

Dim-origines proposal (420 kEuro) not obtained.

CNES concrete support under discussion
co-PIs:
F. Boulanger, A. Ritacco

2030-2031

Expected launch

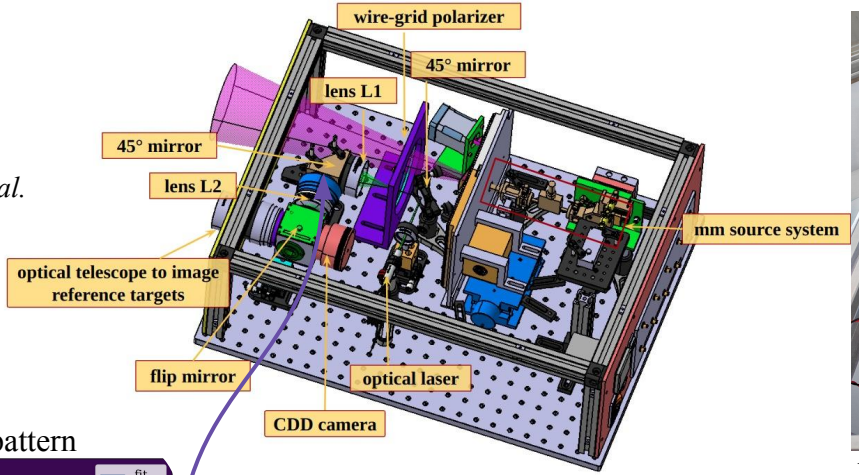
EUTELSAT GROUP

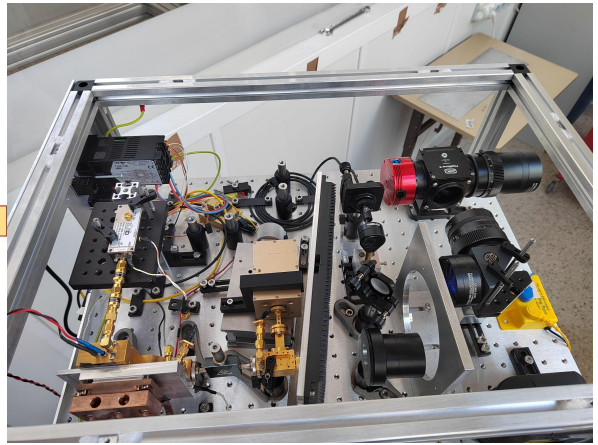
Funded so far by

Built up an international collaboration

COSMOCal prototype @ 260 GHz

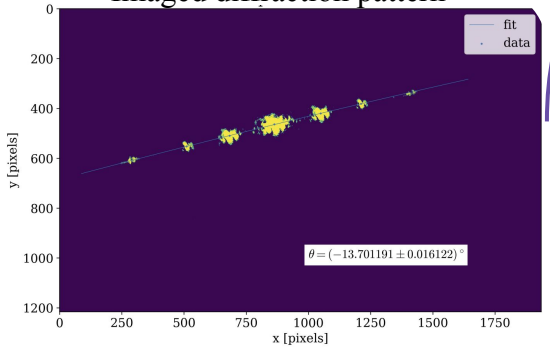
Concept inspired by
Johnson et al. 2015,
Nati et al. 2017, Coppi et al. 2022, Dunner 2021





Fully assembled

Imaged diffraction pattern

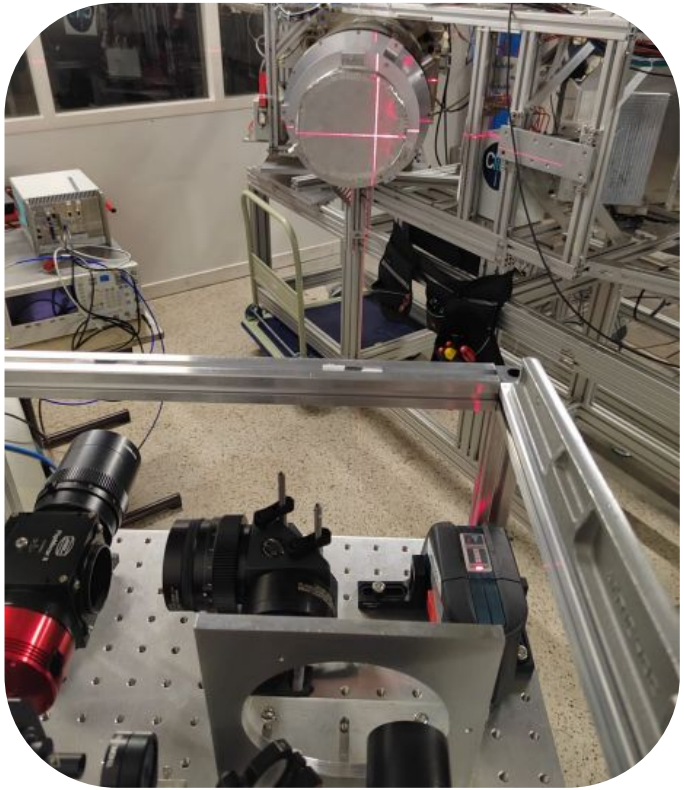


Goal: 0.1 deg.
Results: 0.06 deg.

In laboratory tests
@ LPSC laboratory

Ritacco et al. 2024 PASP 136 115001

System accuracy: laboratory tests

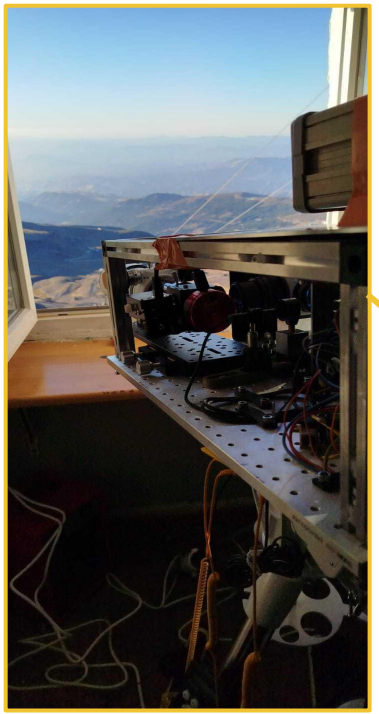


We have performed a full characterization in the laboratory of the LPSC in Grenoble before going to install it in Spain.

See Sofia Savorgnano's talk.

Ritacco, Bizzarri, Savorgnano et al. 2024 PASP 136 115001

COSMOCal full tests at a ground based telescope facility: IRAM 30m



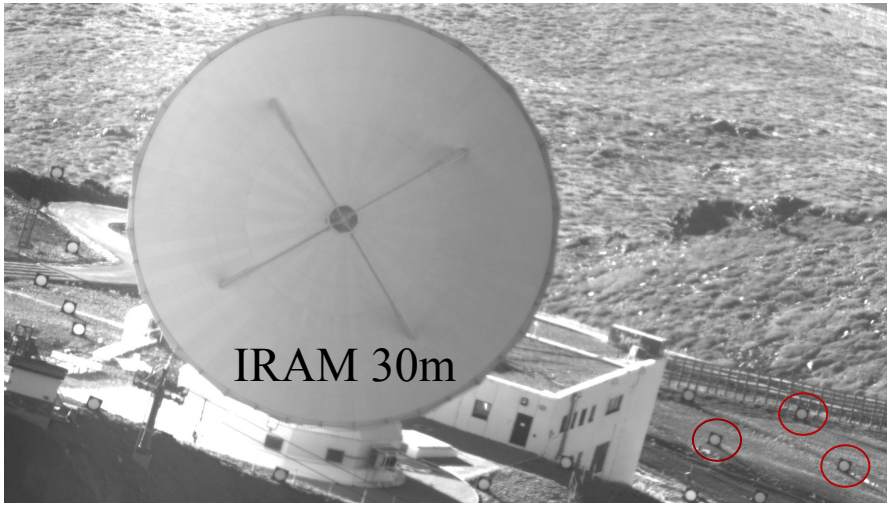
Goals:

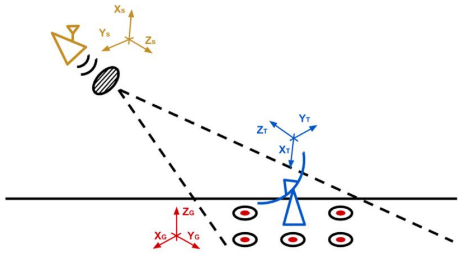
- testing photogrammetry;
- response of a mm continuum camera;
- study instrumental effects in the interface between a large antenna and COSMOCal;
- check the consistency between COSMOCal polarization angle and NIKA2's one.

See Sofia Savorgnano's talk.

3 Photogrammetry

We must link directly the **orientation of the COSMOCal output polarization with** the reference frame of **the 30m antenna.**





Ground references

Roll angle between the box and the coordinates of the IRAM telescope.

Data analysis is ongoing.

Eutelsat partnership

Cooperation for new space

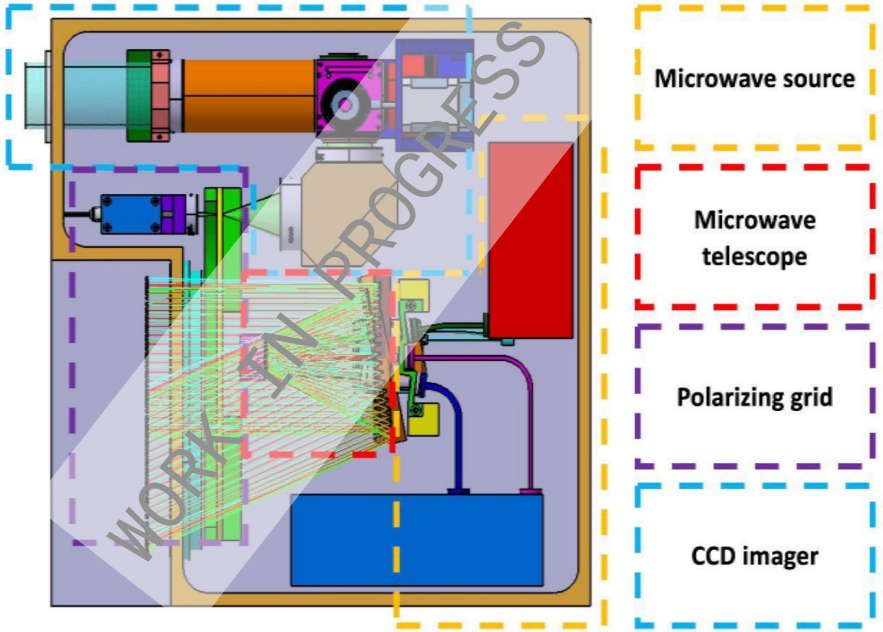
- Partnership initiated through CENSUS in February 2024.
- COSMOCal to be launched in 2030-2031 on a platform of Eutelsat Group in GEO orbit.
- Our request: **source visible from both Europe and Atacama.**
- Payload design coordinated with engineers from Eutelsat Group.
- COSMOCal specifications to be included in Eutelsat's call for tender to be issued in a couple of years.

COSMOCal space payload

CHALLENGES

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

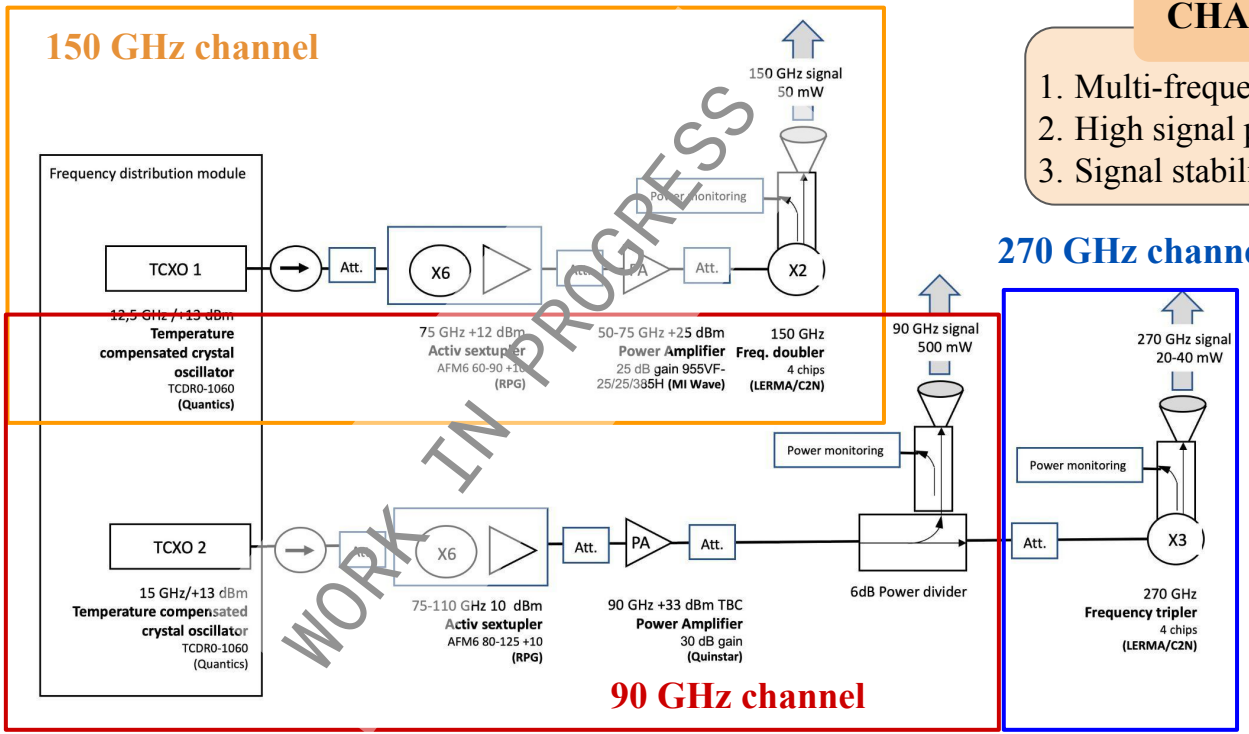
Lead: **P. Morfin (LPENS)**



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

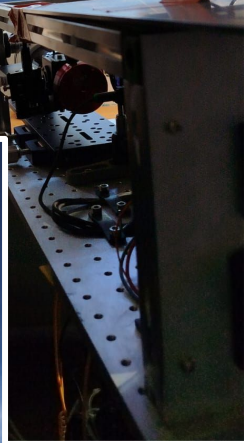
Lead: **J. Treuttel** (Observatoire de Paris)

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

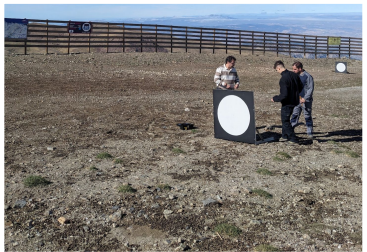
Design of a **high-power** microwave source with **three frequency channels** (90, 150 & 270 GHz).

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.



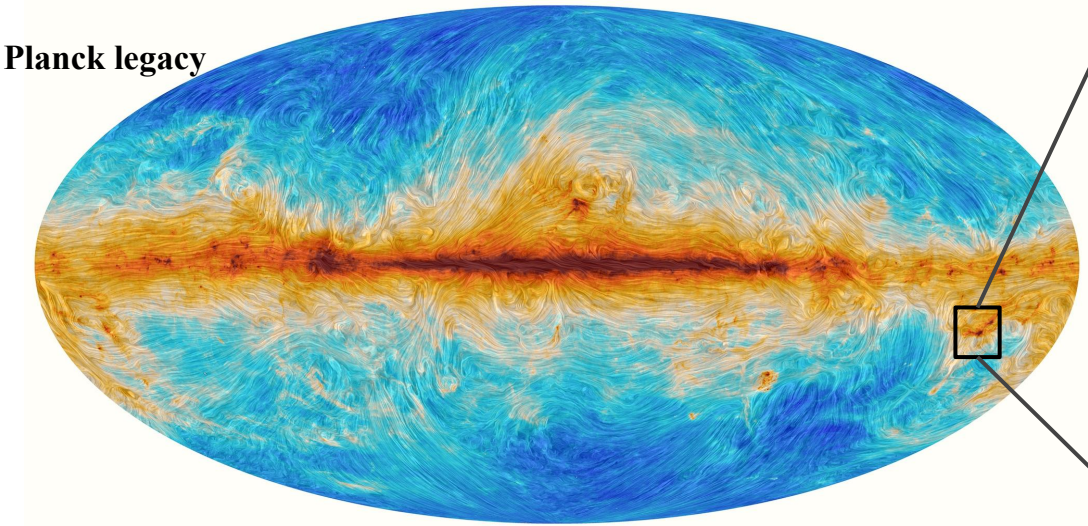
THANKS

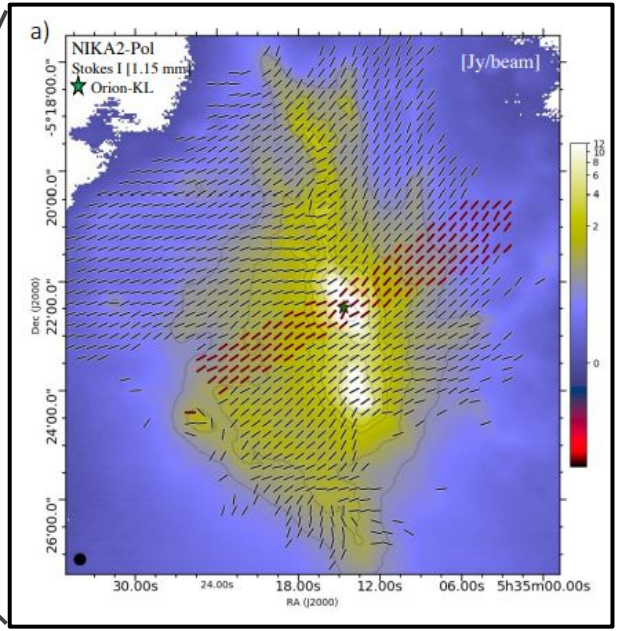


Magnetized dusty interstellar medium

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

COSMOCal work plan

➔ Payload study & mission concept

- **WP1 - Design of payload subsystems**
  - Multi-frequency microwave source
  - Microwave telescope
  - Polarizer & associated optics for metrology
- **WP2 - Payload models**
  - Engineering model: laboratory proto-type of space payload
  - Structural and thermal model interfaced with space platform
  - Studies and tests
- **WP3 - Calibration methodology**
  - Observational procedure
  - Data analysis procedure and tools
  - Data simulations & mission concept