

QUIJOTE: status and future plans

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The QUIJOTE experiment

QT-1 and QT-2: Cross-Dragone telescopes, 2.25m primary, 1.9m secondary.

QT-1. Instrument: MFI.

11, 13, 17, 19 GHz.

FWHM=0.92°-0.6°

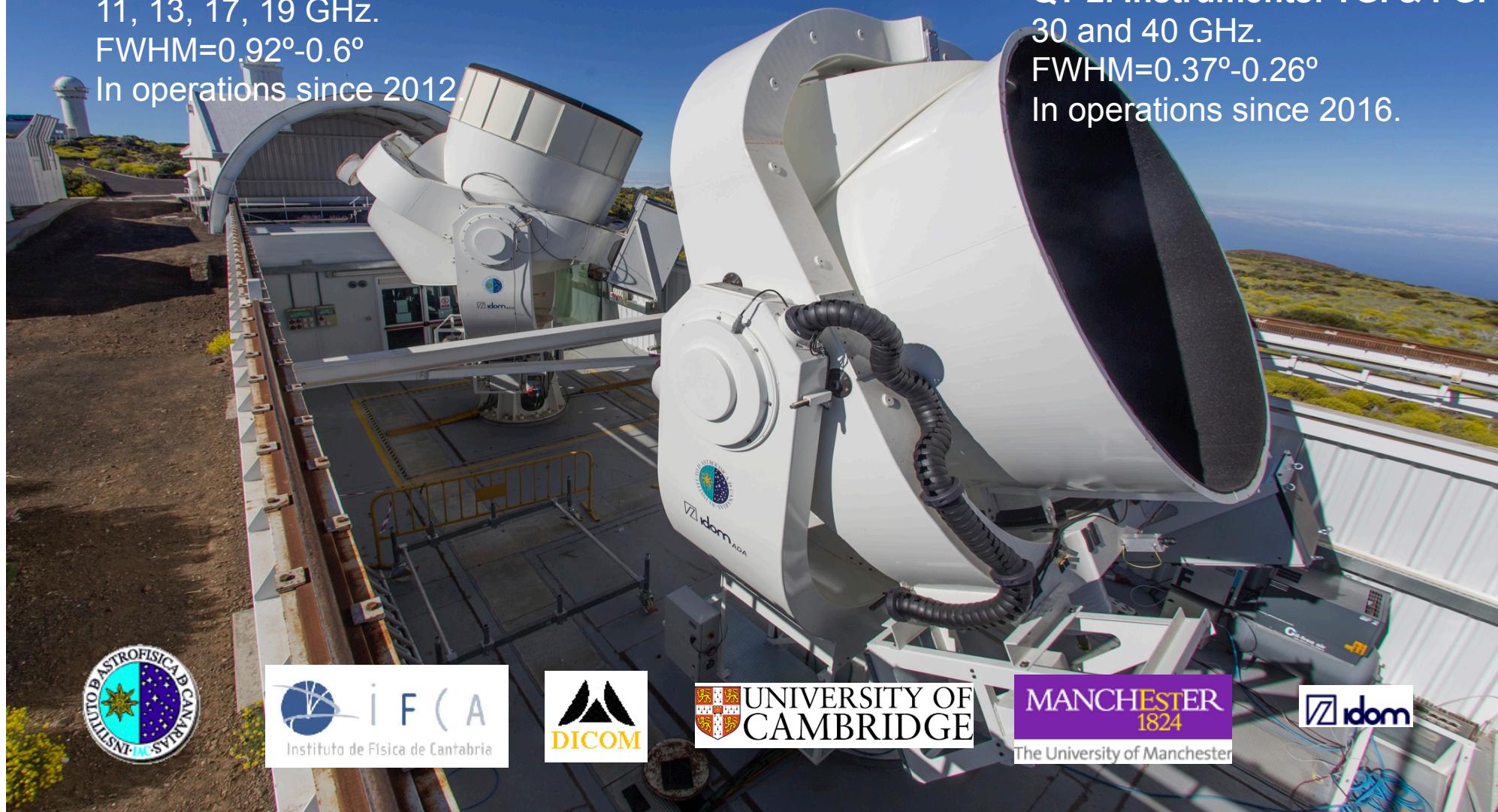
In operations since 2012.

QT-2. Instruments: TGI & FGI

30 and 40 GHz.

FWHM=0.37°-0.26°

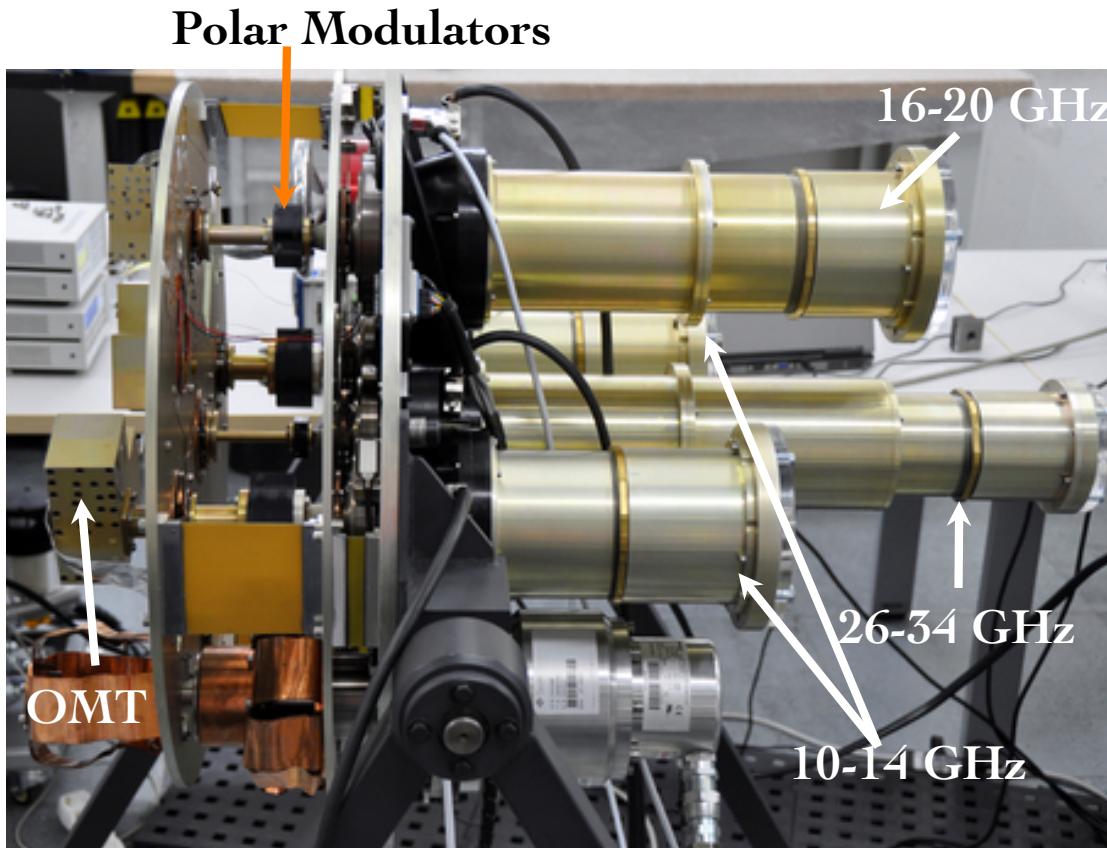
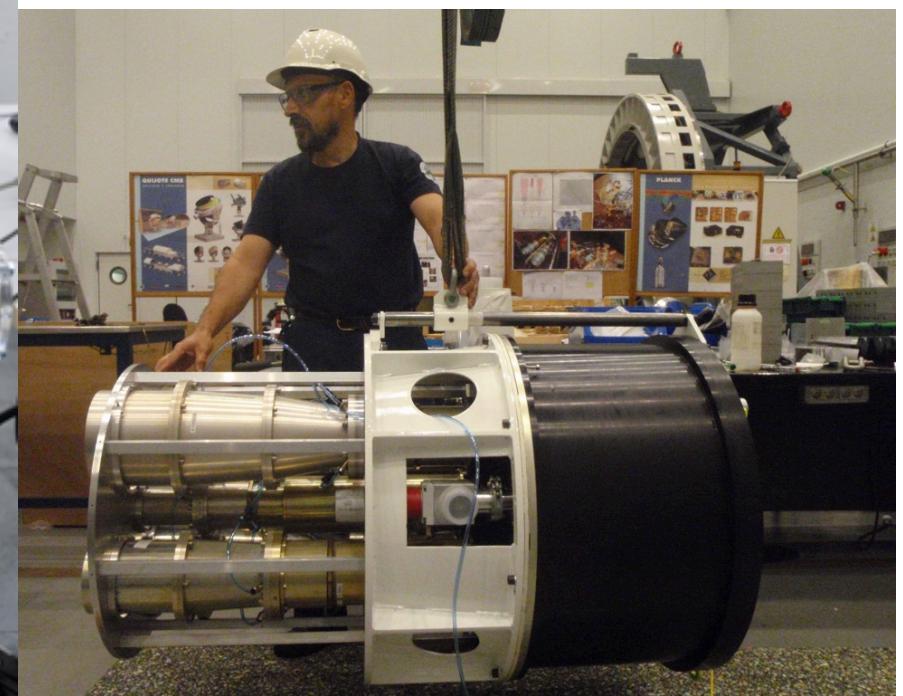
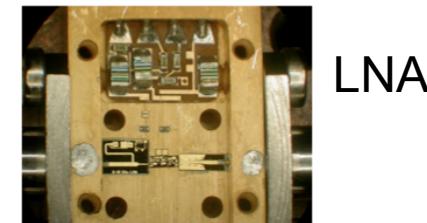
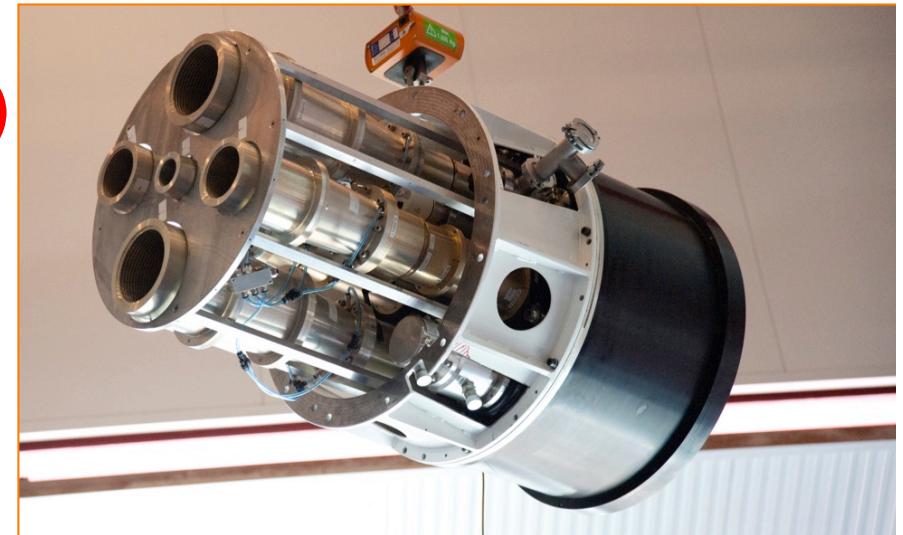
In operations since 2016.





MFI Instrument (10-20 GHz)

- ❖ **Operations:** Nov. 2012 – Dec. 2018.
- ❖ 4 horns, 32 channels. Covering 4 frequency bands: 11, 13, 17 and 19 GHz.
- ❖ **Sensitivities:** ~400-600 $\mu\text{K s}^{1/2}$ per channel.





Science with QUIJOTE first instrument (MFI)

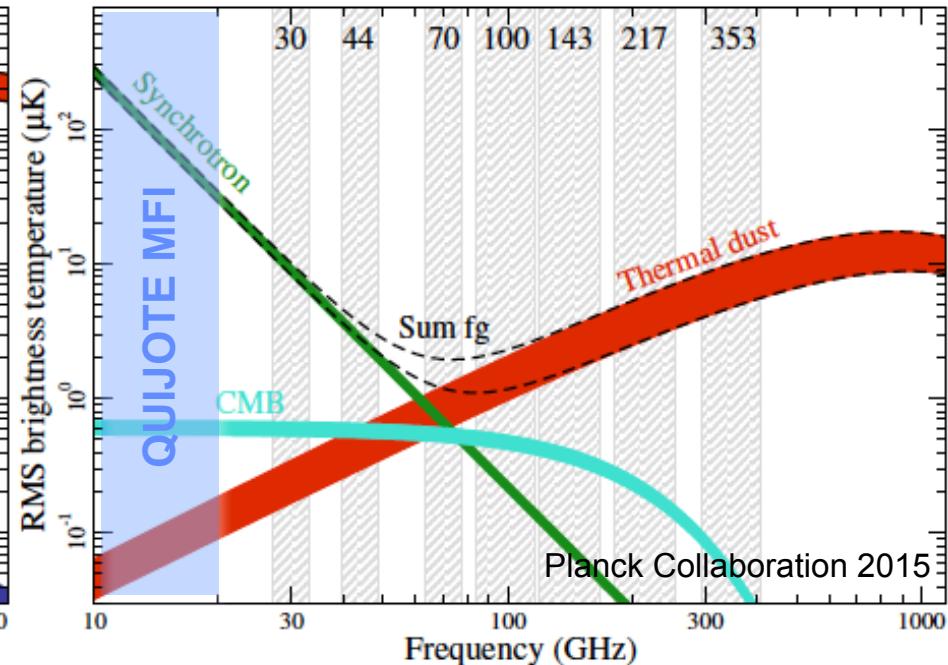
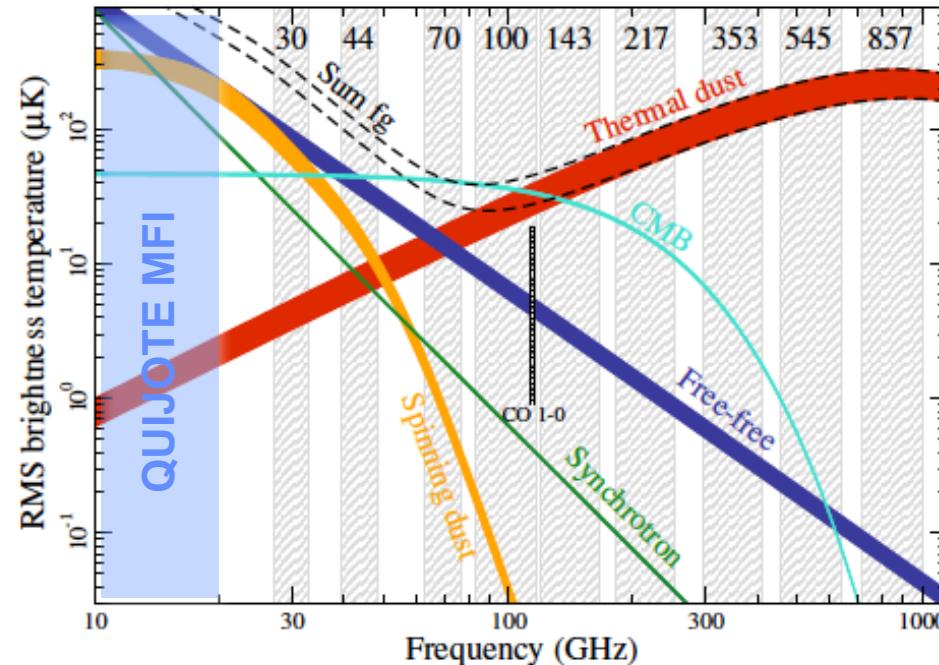
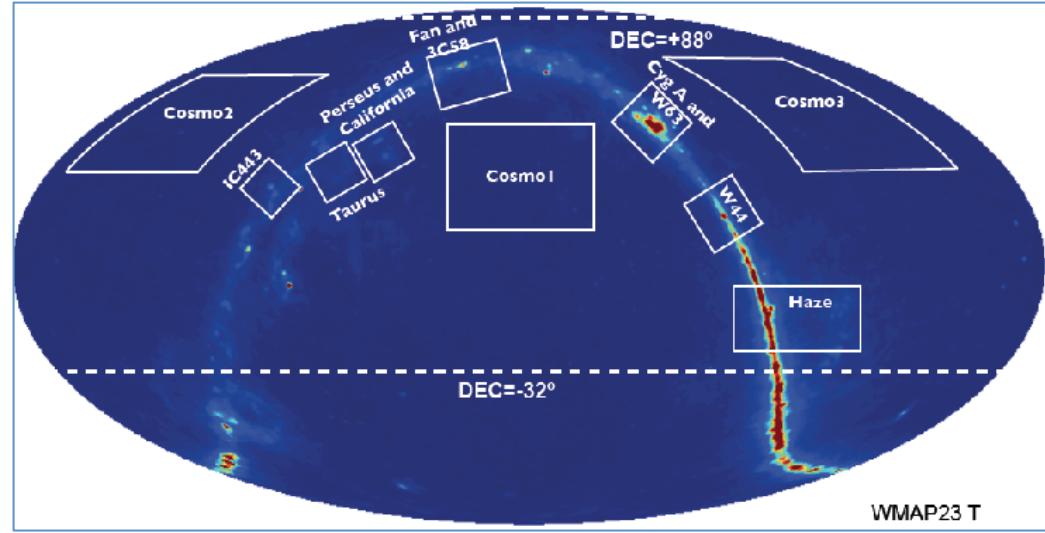


Excellent complement to PLANCK at low frequencies. Legacy for future experiments (→Litebird)

MFI Science phase

- Wide survey (10,800h)
- Cosmological fields (6,500h)
- Daily calibrators (Crab, Cass A, Jupiter, sky dips)
- Galactic centre and Haze (930h)
- Perseus molecular cloud (600h)
- Fan region and 3C58 (460h)
- Taurus region (450h)
- SNRs (W44, W47, IC443, W63) (900h)

Total: ~25,500 h of MFI data (2.9 effective years), with ~50% efficiency.

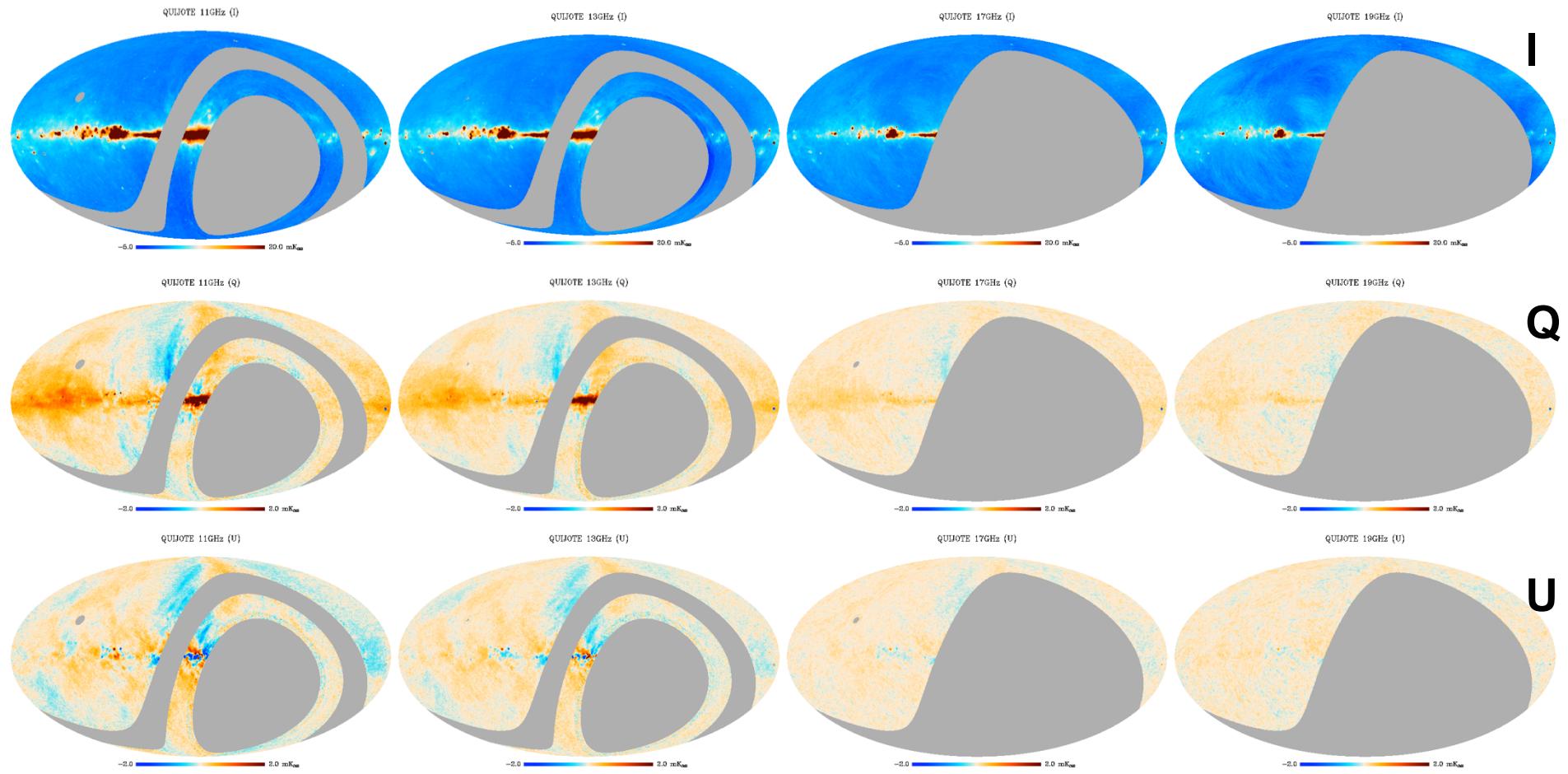




Wide survey with the QUIJOTE MFI (10-20 GHz)

Preliminary maps

(Smoothed to 1°)



QUIJOTE 11GHz

QUIJOTE 13GHz

QUIJOTE 17GHz

QUIJOTE 19GHz

Q

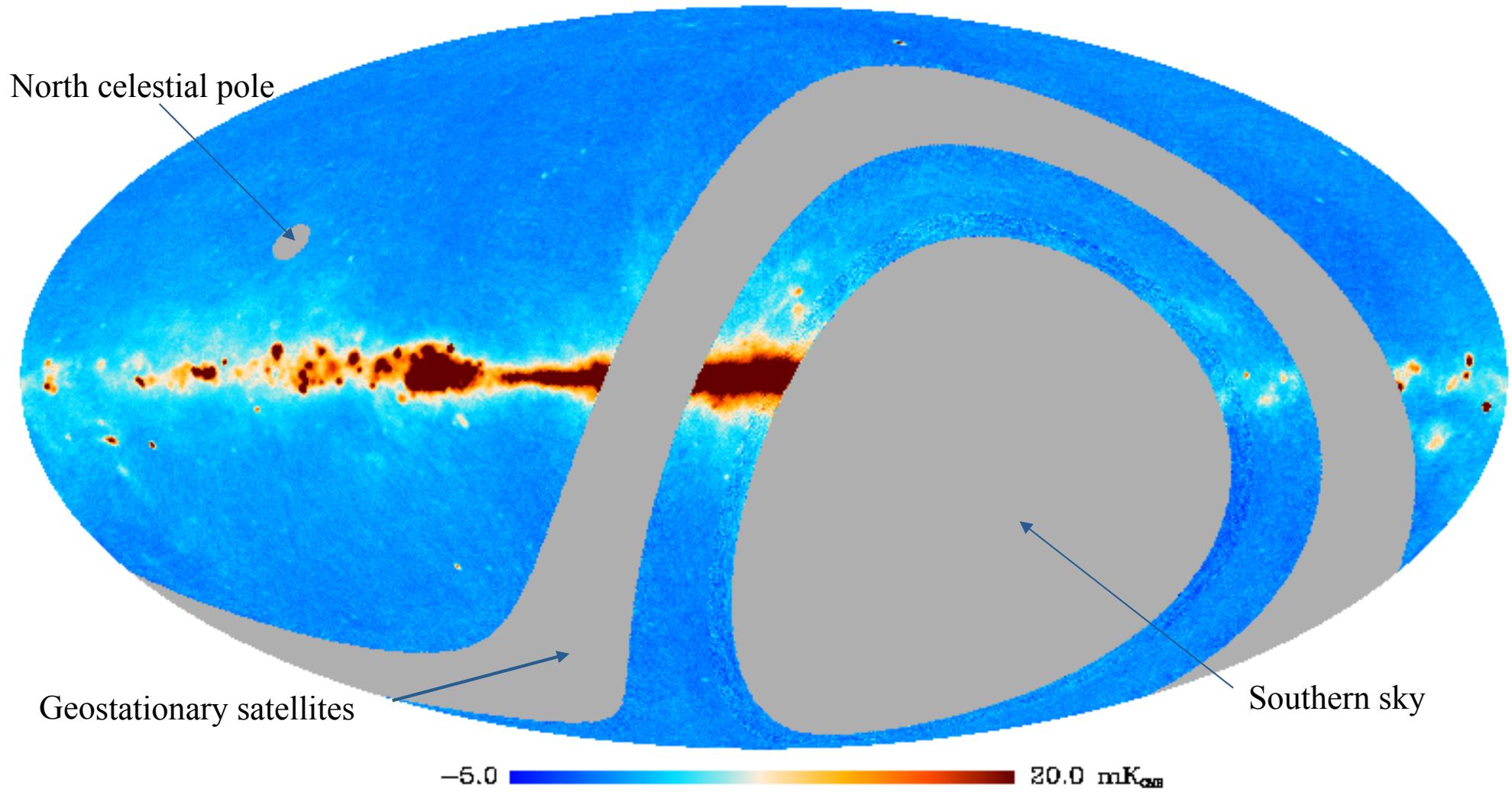
U



Wide survey with the QUIJOTE MFI (10-20 GHz)

QUIJOTE 11GHz (I)

Preliminary maps
(Smoothed to 1°)

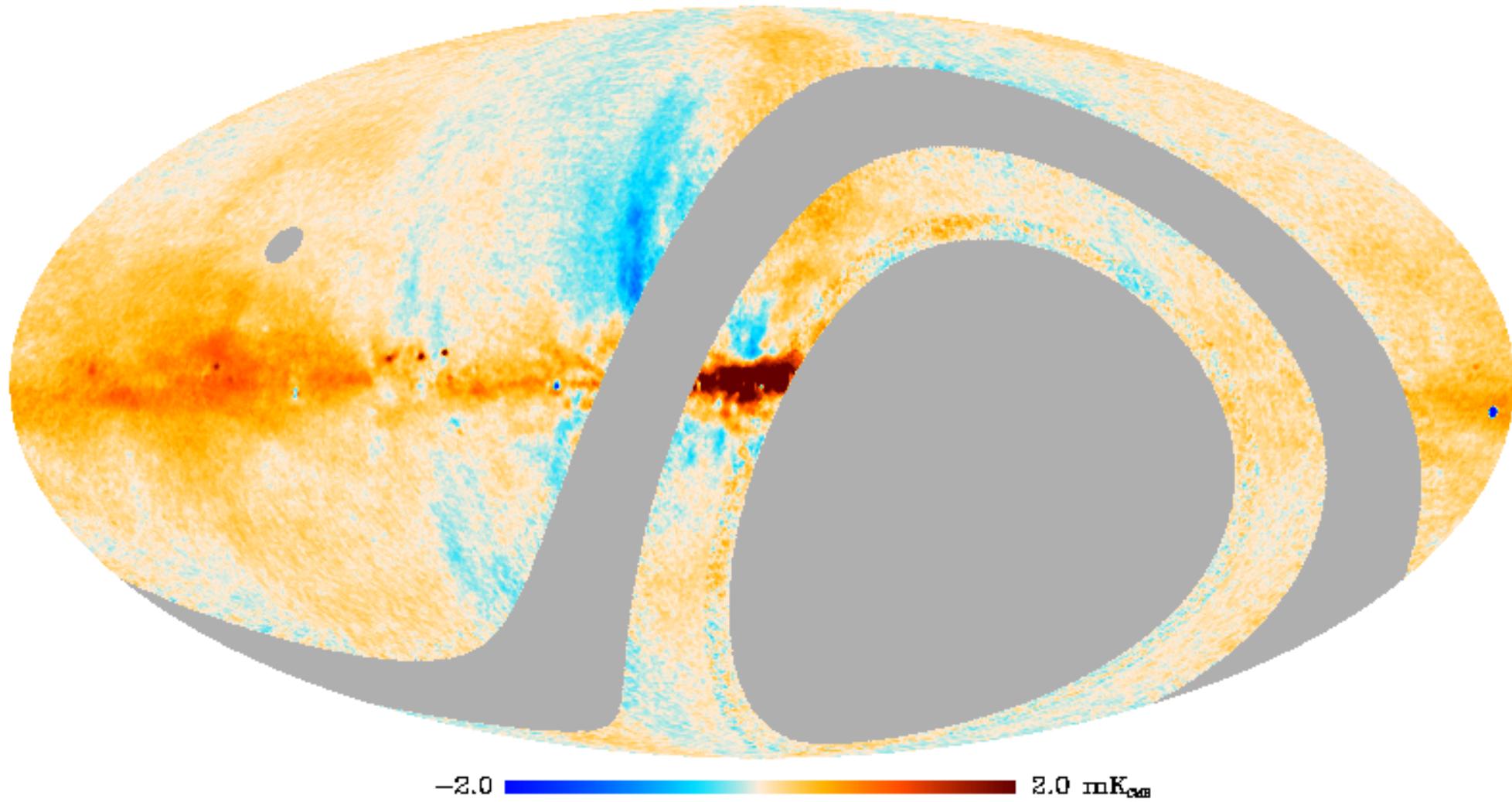




Wide survey with the QUIJOTE MFI (10-20 GHz)

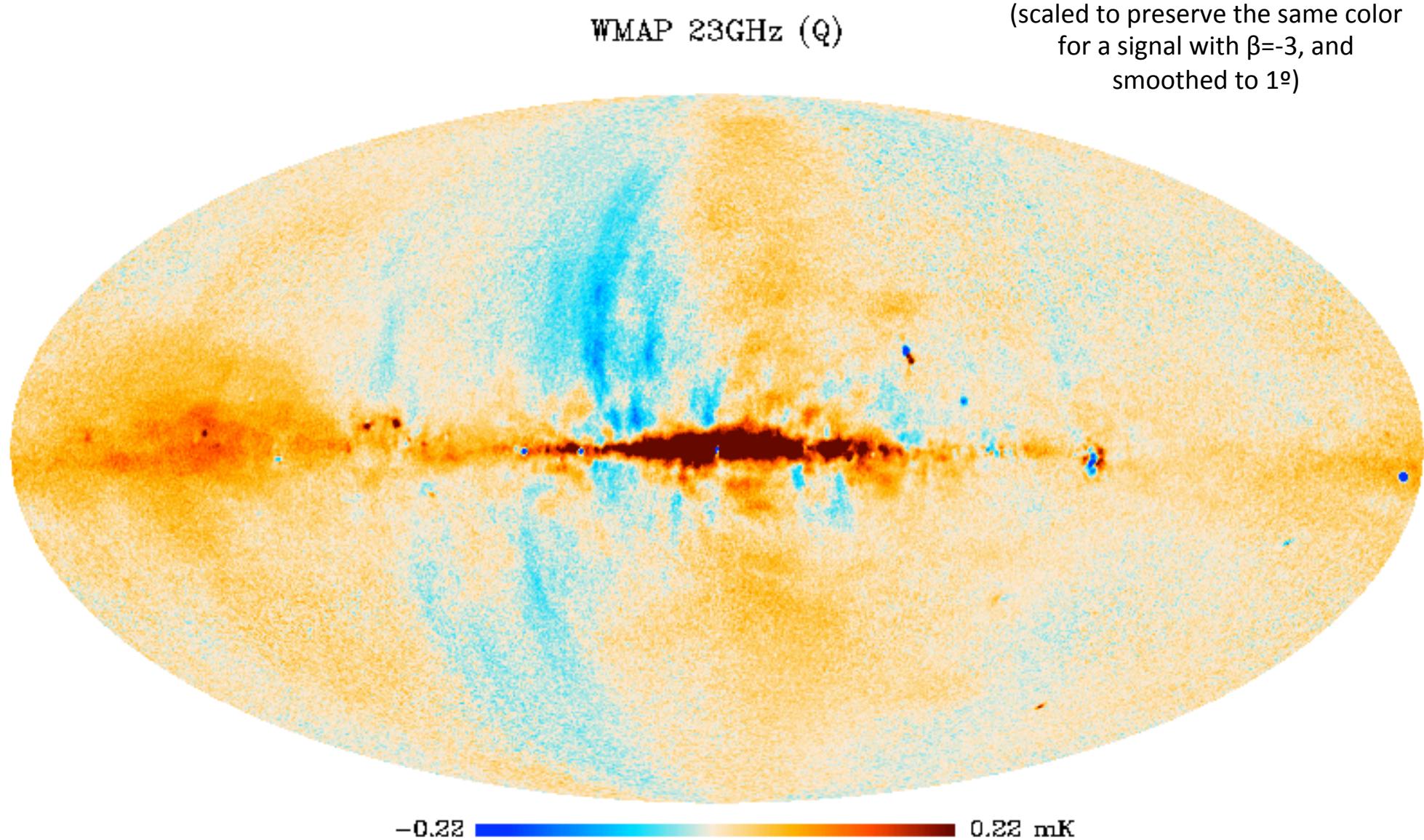
Preliminary maps
(Smoothed to 1°)

QUIJOTE 11GHz (Q)





Wide survey with the QUIJOTE MFI (10-20 GHz)

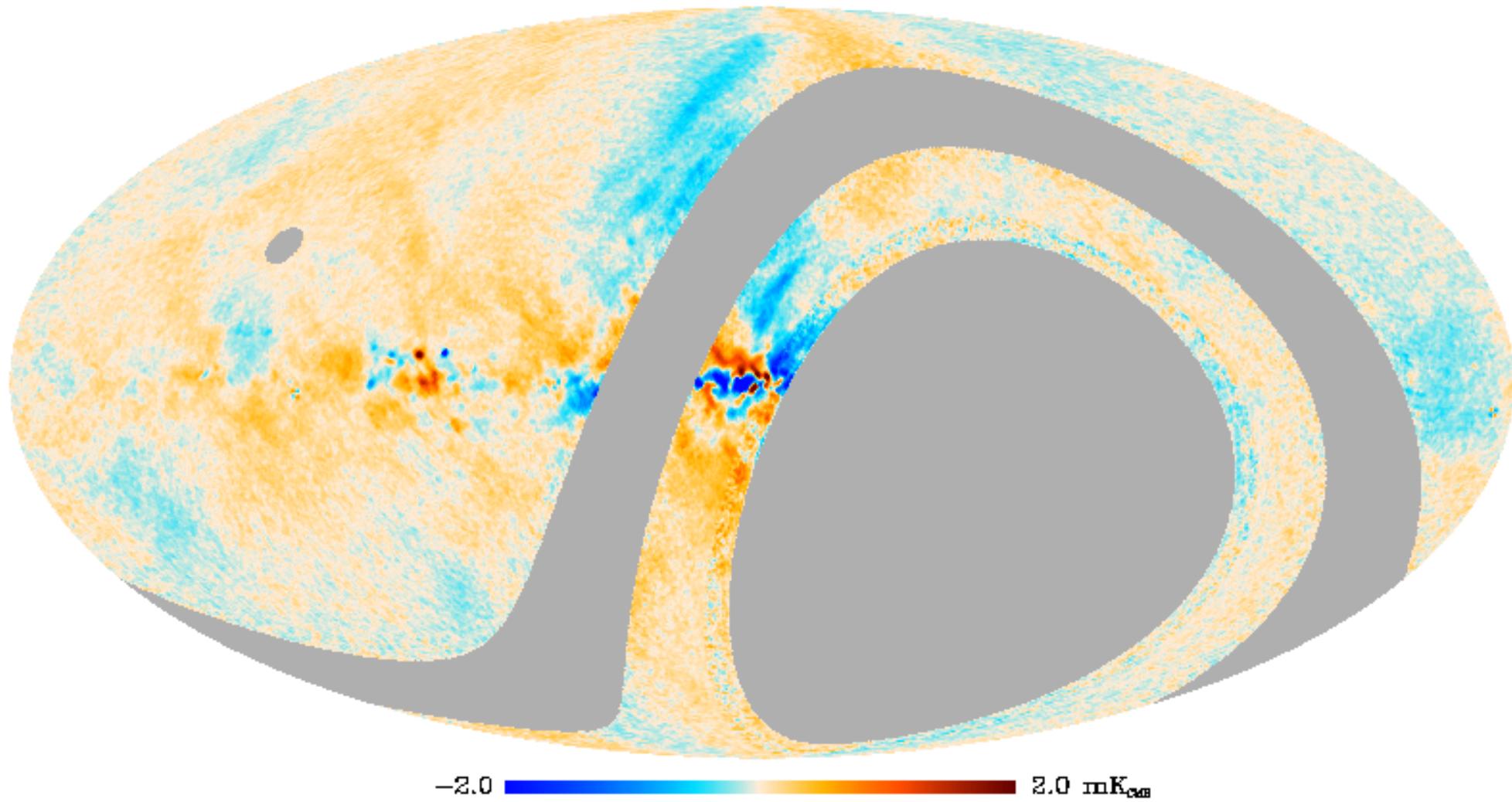




Wide survey with the QUIJOTE MFI (10-20 GHz)

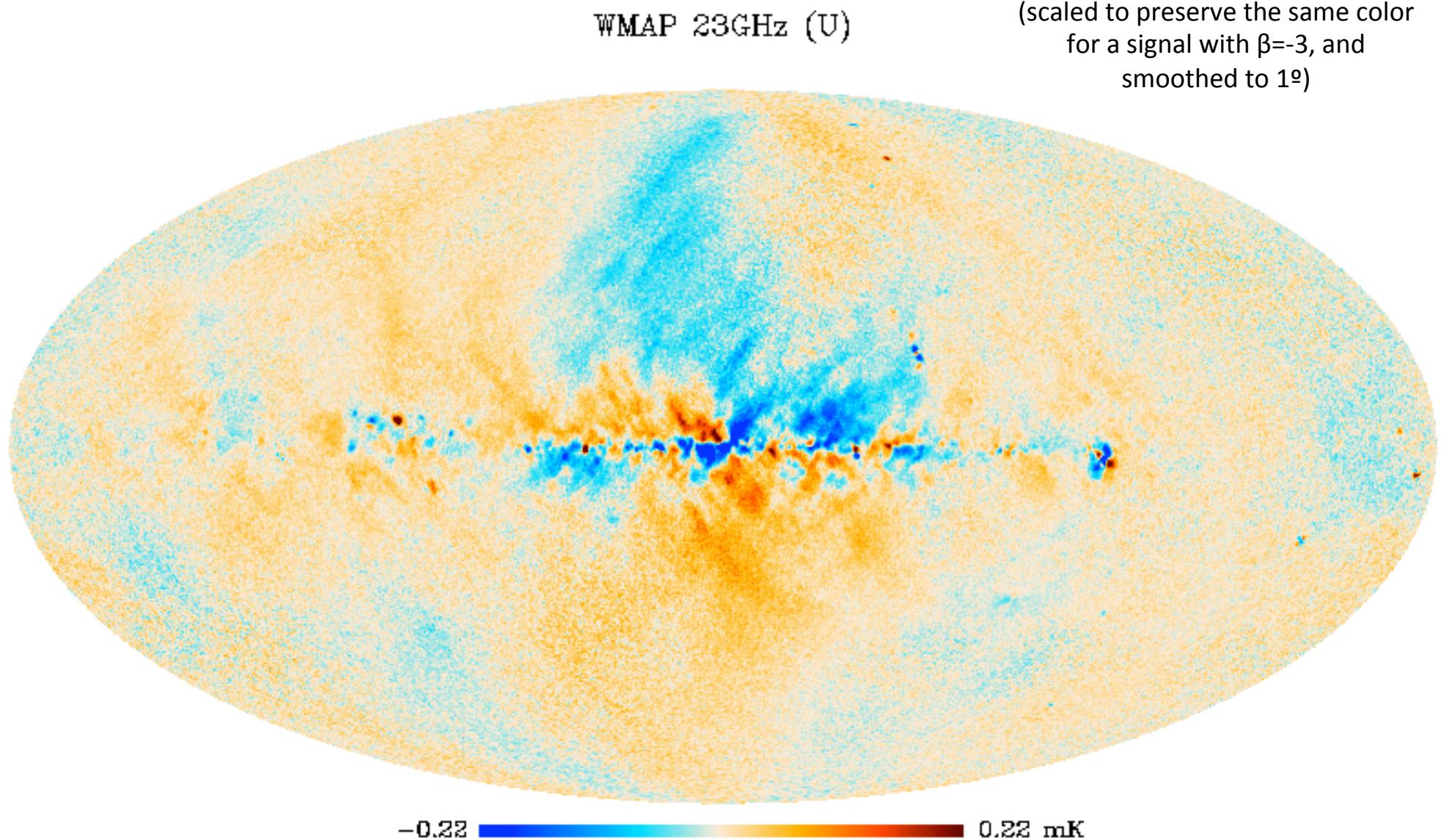
Preliminary maps
(Smoothed to 1°)

QUIJOTE 11GHz (U)





Wide survey with the QUIJOTE MFI (10-20 GHz)





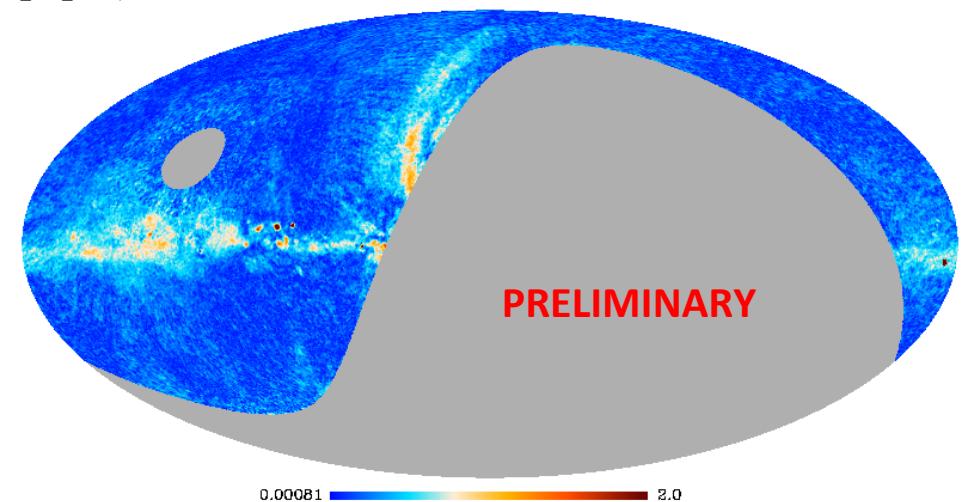
Wide survey with the QUIJOTE MFI (10-20GHz)



Papers: QUIJOTE wide-survey (in preparation, to be submitted soon):

- I. A northern sky survey at 10-20GHz with the Multi-Frequency Instrument.
- II. Galactic AME sources in the MFI wide survey.
- III. Analysis of the polarised synchrotron emission at the power spectrum level in the MFI wide survey.
- IV. The FAN region as seen by QUIJOTE-MFI
- V. The North Galactic Spur as seen by QUIJOTE-MFI.
- VI. Component separation in intensity with the QUIJOTE-MFI wide survey
- VII. Component separation in polarization with the QUIJOTE-MFI wide survey.
- VIII. Radiosources in the QUIJOTE-MFI wide survey.
- IX. W49, W51 and IC443 SNRs as seen by QUIJOTE.
- X. AME Lambda Orionis (Joint QUIJOTE-CBASS paper)

QUIJOTE PI 11GHz



Maps will be publicly available once the first paper is accepted for publication.

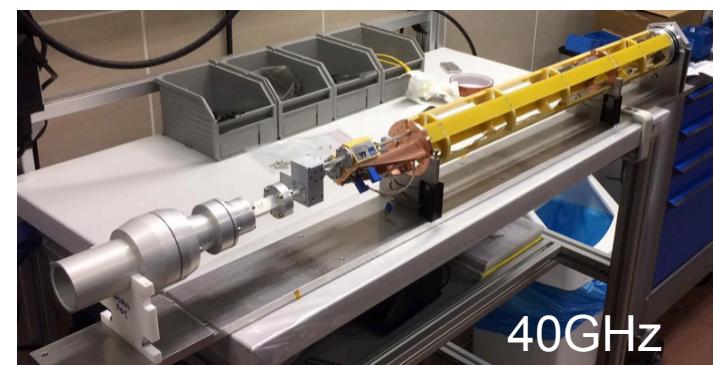
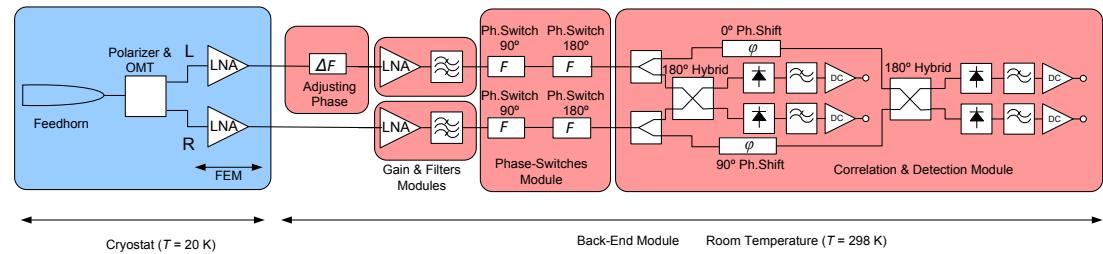
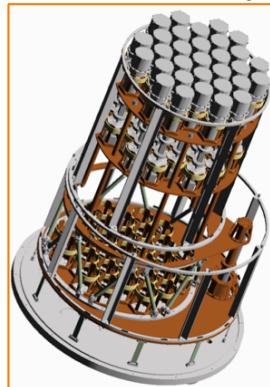
(Preliminary results presented in the CMBforegrounds18 conference, Tenerife, October 15-18, 2018).

<http://www.iac.es/congreso/cmbforegrounds18/>



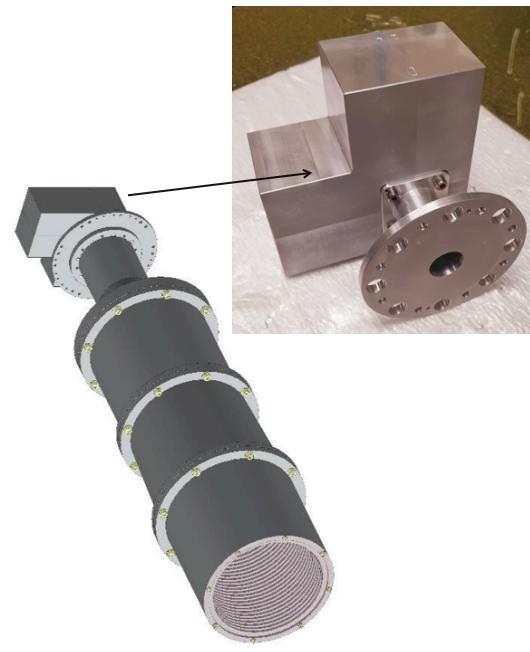
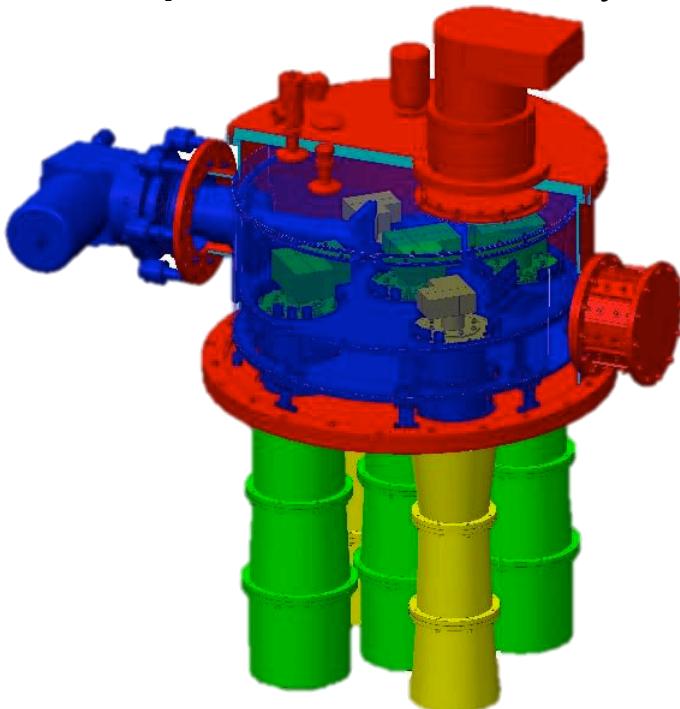
TGI (30 GHz) and FGI (40GHz) instruments

- ❖ **TGI**: 31 pixels at 30GHz. Measured sensitivity: $50 \mu\text{K s}^{1/2}$ for the full array. First light May 12th 2016.
- ❖ **FGI**: 31 pixels at 40GHz. Sensitivity: $60 \mu\text{K s}^{1/2}$ for the full array. First observations in 2018-19 (with 14 pixels). 
- ❖ **Joint TGI/FGI observations started in 2018**. Now changing configuration and fixing problem with the cryostat.



MFI2 Instrument (10-20 GHz)

- ❖ **MFI upgrade (MFI2).** Fully funded. Aim: to increase the integration speed of the MFI by a factor 3. (Mainly coming from the new LNAs).
- ❖ **5 horns.** Two covering the 10-14GHz band, and three covering 16-20GHz.
- ❖ **Full digital back-end (FPGAs) → RFI removal.**
- ❖ **Status:** Cryostat fabricated. Opto-mechanical components being fabricated. Assembly in the coming months.
- ❖ **Operations:** 3 effective years, starting summer 2020.



Teide Observatory (Tenerife)

CMB polarization experiments:

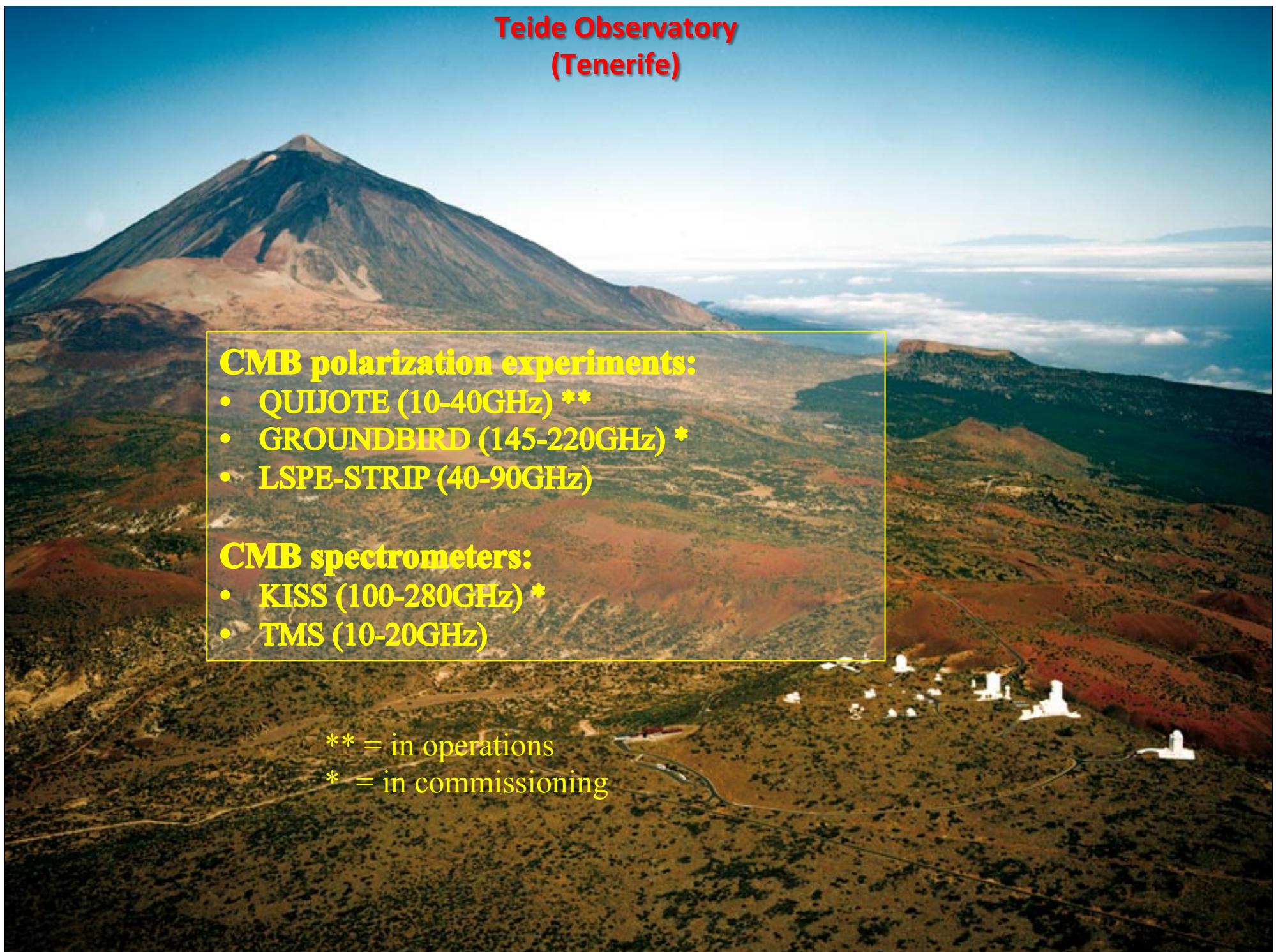
- QUIJOTE (10-40GHz) **
- GROUNDBIRD (145-220GHz) *
- LSPE-STRIP (40-90GHz)

CMB spectrometers:

- KISS (100-280GHz) *
- TMS (10-20GHz)

** = in operations

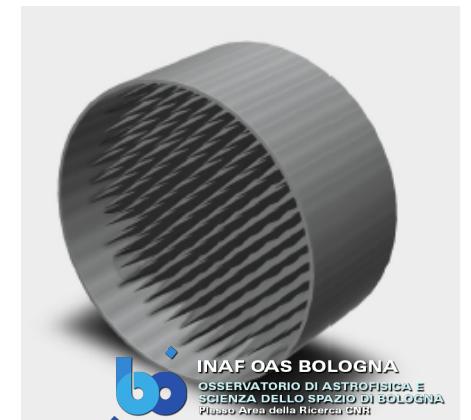
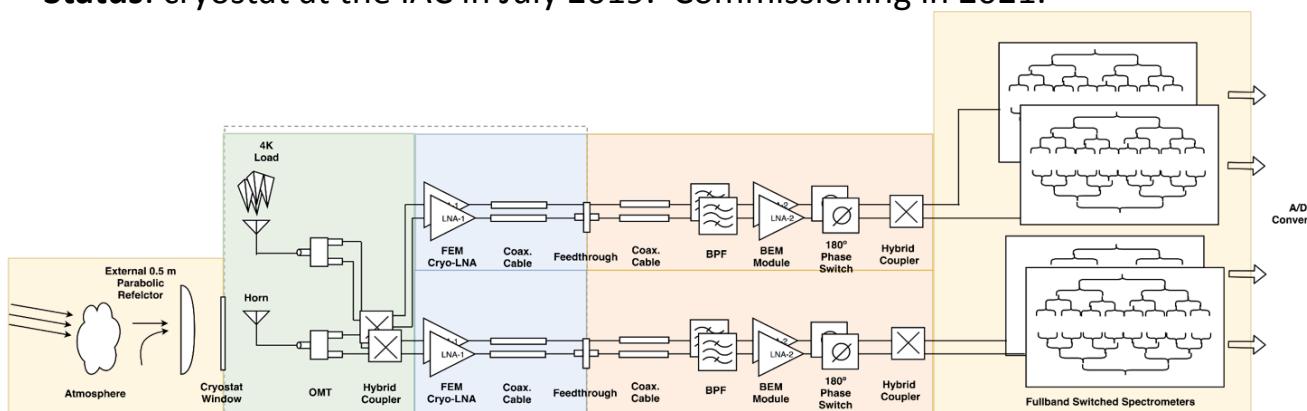
* = in commissioning





Tenerife Microwave Spectrometer (TMS), 10-20GHz

- IAC project. Already funded.
- **Science driver:** Ground-based [low resolution spectroscopy](#) observations in the 10-20GHz range to characterize foregrounds (monopole signals; spectral dependence of monopole signals; ARCADE results) and CMB spectral distortions. Provides frequency intercalibration-calibration for QUIJOTE.
- **Proposed instrument:**
 - FEM cooled to 4-10K (HEMTs).
 - Reference load to 4K in collaboration with INAF OAS, Bologna.
 - Novel FTS spectrometer providing \sqrt{N} increase in sensitivity with wideband simultaneous acquisition.
 - $\sim 2\text{deg}$ beam, 0.25 GHz spectral resolution (40 bands).
- **Location:** Teide Observatory (former VSA enclosure). Independent pedestal (copy of a QUIJOTE telescope). Full sky dome.
- **Status:** cryostat at the IAC in July 2019. Commissioning in 2021.





KID Imager-Spectrometer Survey

Grenoble (Institut Néel, LPSC & IPAG), Tenerife (IAC) & Roma (La Sapienza)

KISS : Low-resolution ($\Delta\nu = 1\text{-}3$ GHz) Martin-Puplett interferometer (MPI) coupled to a **KID** based camera (100-280 GHz). Visitor instrument mounted at QT-1 telescope (Teide Observatory, Tenerife).

Design

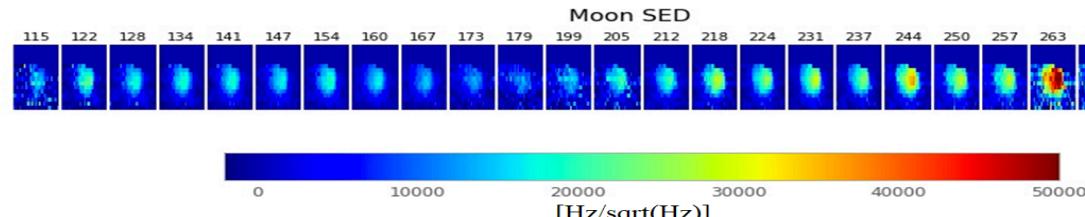
- NIKA camera adapted for KISS optical design.
- Large frequency band (100-300GHz) 600 KID arrays.

Scientific motivation and concept

- Low resolution spectroscopy to separate the different components in the mm-emission of low-z clusters.
- Extract physical properties of the clusters from the SZ signal: total pressure (tSZ), temperature (RtSZ), LOS velocity (kSZ).

Status

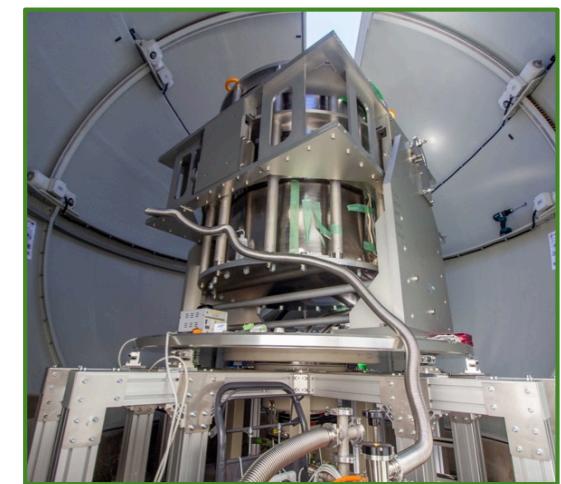
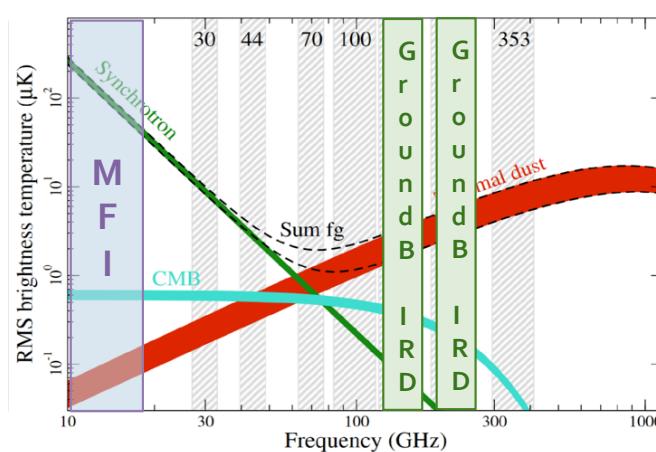
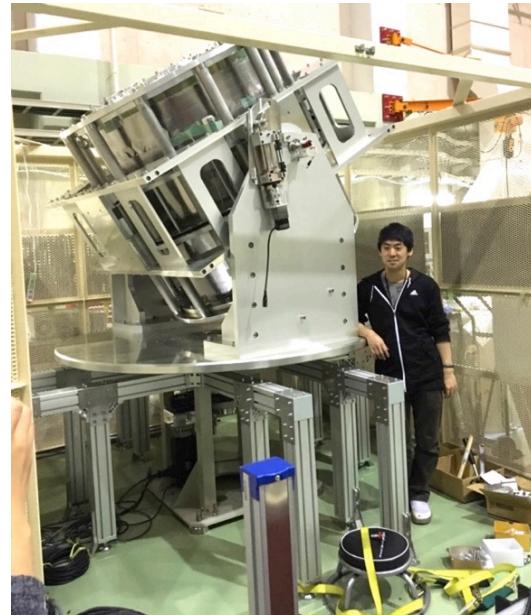
- Installation completed (January 2019) → commisioning.
- Sensitivities as expected ($\sim 0.7\text{mK}/\text{Hz}^{1/2}$).
- Observations: Moon, Jupiter. New obs run in september.



GroundBIRD

- Installation completed. In commissioning phase.
- Location: Teide Observatory
- Operation plan: 3 years (2019-2021).
- **145 GHz** (660 KIDs) and **220 GHz** (224 KIDs)
- Expected sensitivity:
 $300 \mu\text{K}\cdot\text{sqrt(s)}/\text{detector}$.
Full array: $12 \mu\text{K}\cdot\text{sqrt(s)}$ @ 145 and 20
 $\mu\text{K}\cdot\text{sqrt(s)}$ @ 220 GHz.

- High-speed rotation scans (20 rpm)
- 20-deg FOV with angular resolution of 0.6 deg @ 145 GHz
- Aims: reionisation and recombination bumps
- Final goal: $r=0.01$.





QUIJOTE: status and future plans



QT1 + MFI (10-20 GHz). 2012-2018.

- Observations completed. COSMO fields (> 6,500h), Wide survey (>10,000h), galactic fields (Taurus, W49, IC443, W63, FAN, galactic center). Results published. Best upper limit to date on AME pol fraction (0.2%). Wide survey data release will happen soon. Legacy value (e.g. Litebird).

----- Funded -----

QT2 + TGI (30 GHz) and FGI (40 GHz). 2018-2024.

- 2018-: Joint TGI/FGI operation in the same cryostat (14/15).
- Observing plan for TGI/FGI science phase: cosmo survey in 3 effective years.

QT1 + MFI2 (10-20 GHz). 2020-2024.

- Funds secured. Cryostat in fabrication. Aim: to increase the sensitivity by a factor of 3.

TMS (10-20GHz). 2021-2024.

- Spectroscopy. Absolute scale for QUIJOTE. Synchrotron monopole.

Combination with other experiments at Teide Obs. 2021-2024.

- Groundbird, LSPE-STRIP (\rightarrow measurements at >90GHz).

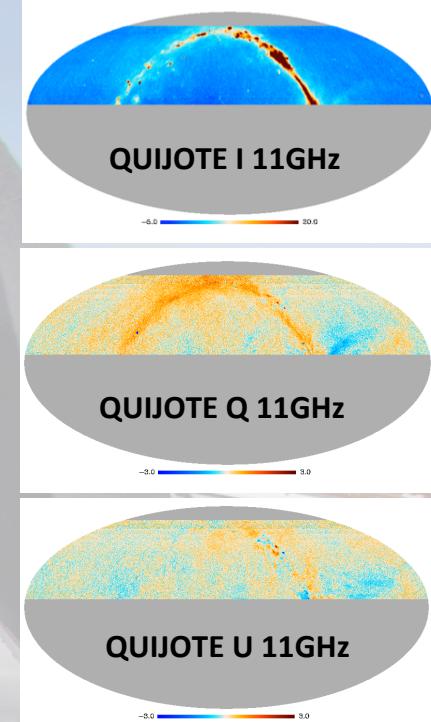
----- Not funded yet -----

Extension to Southern Hemisphere. 2023-2027?

- Extension QUIJOTE-MFI/MFI2 to south is being studied (ZA? Atacama?)
- E-CMB. Plans for full-sky low frequency survey ELFS @6m. \rightarrow Synergy grant.

ELFS north from Teide Observatory. 2024-2027?

- E-CMB. ELFS @ 6m. Re-using QUIJOTE instrumentation (MFI2)?



One postdoc position available in Tenerife (IAC)

LSPE-STRIP and preparation of joint analysis of the STRIP and QUIJOTE data sets.
2 years duration.

Deadline for applications: October 1st, 2019.

<https://jobregister.aas.org/ad/6a32dbb9>

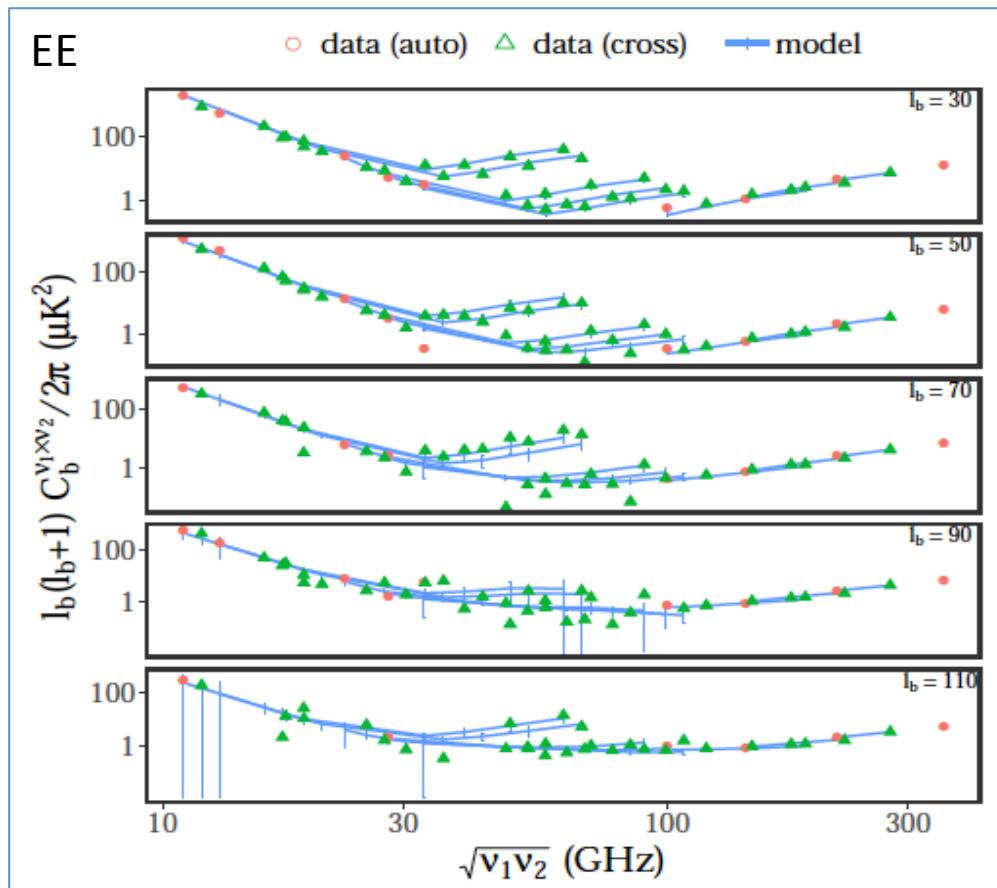
EXTRA SLIDES



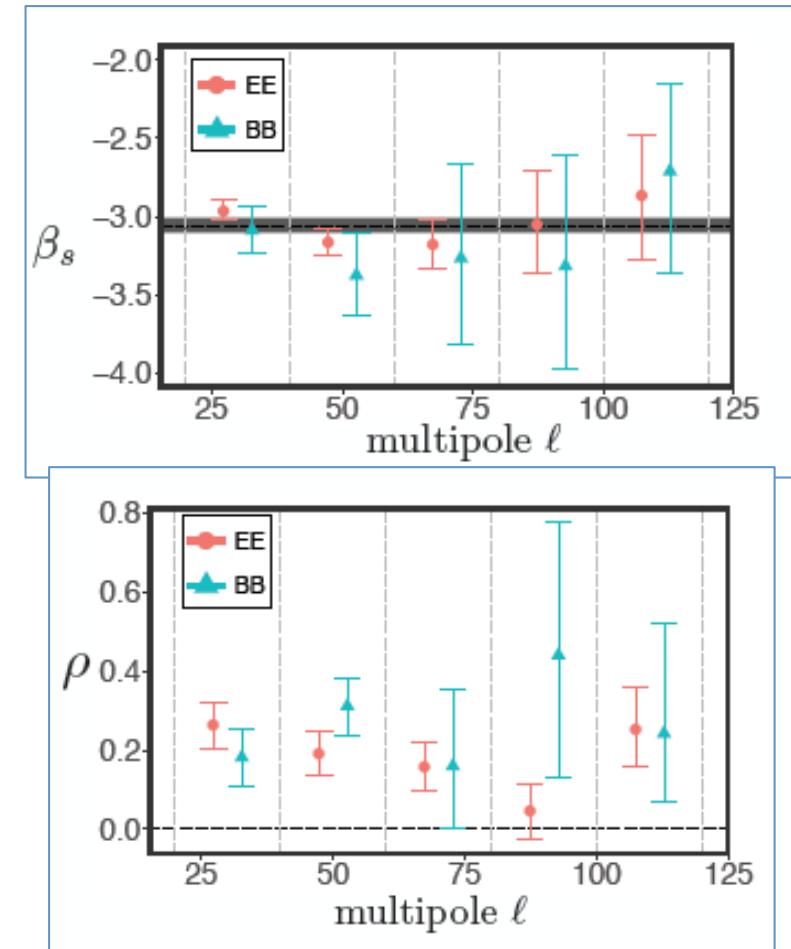
QUIJOTE-MFI wide survey results: synchrotron polarization



- Auto- and cross-spectra of QUIJOTE, WMAP, PLANCK maps in northern sky ($|b| > 10^\circ$).
- Pol. Synchrotron spectral index: -3.00 ± 0.05 . [Planck: -3.13 ± 0.13 , S-PASS: -3.22 ± 0.08].
- Dust-synchrotron correlation: $\sim 0.20 \pm 0.06$.
- Variability on sky (compared to other results: Planck Col. XI 2018, Krachmalnikoff et al. 2018).

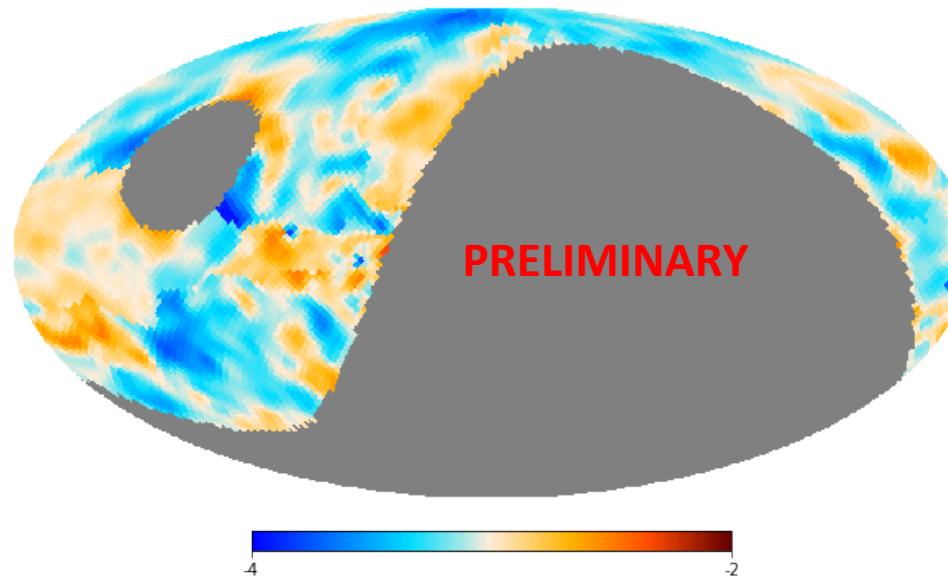


(Vansyngel et al. in prep)

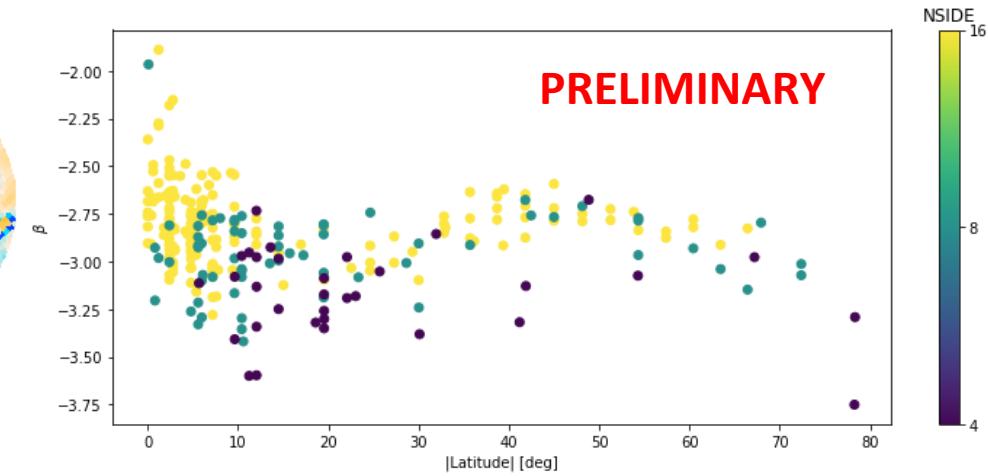


QUIJOTE-MFI wide survey results: component separation

- **Parametric component separation methods** have been tested.
- QUIJOTE-MFI data provide additional information to constrain the synchrotron polarization spectral index from the combination with PLANCK(+WMAP).
- Possibility to explore curvature of the spectral index.
- Preliminary results in polarization.
 - Neural networks (Casaponsa, IFCA). Synchrotron spectral index: -3.08 ± 0.22 . → **variability on sky**
 - Adaptative parametric method FGBuster (Poletti, SISSA). → variability on sky.



Synchrotron spectral index in polarization, using Quijote 11+13 + Planck (Casaponsa et al.)



Synchrotron spectral index in polarization as function of galactic Latitude (Poletti et al.)

QUIJOTE-MFI wide survey results: modelling the AME

- Systematic study of 63 AME sources. Includes 51 targets from PIR XV (2014).
- **Intensity.**
 - QUIJOTE-MFI provides a clean separation of the AME, free-free and synchrotron components. Generally, higher AME and lower free-free.
 - New (unexpected) result: clear correlation of AME/ τ_{dust} with radiation field G_0 .
- **Polarization.** Synchrotron component, and upper bounds on AME emission.

