



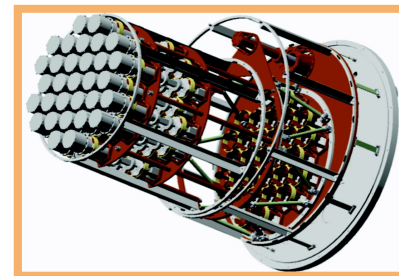
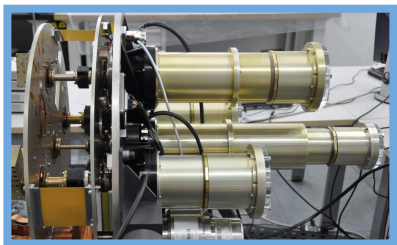
# THE QUIJOTE WIDE-SURVEY MAPS

Federica Guidi  
on behalf of the QUIJOTE collaboration

**VII Meeting on Fundamental Cosmology**



# QUIJOTE: MFI and TFGI



## QT1 & MFI

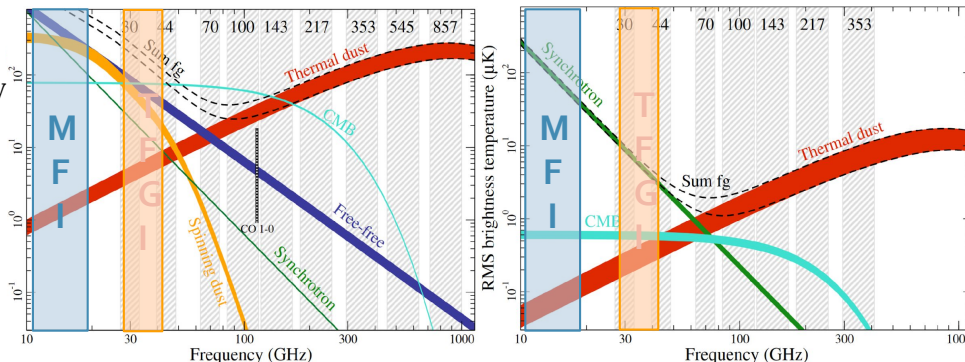
(Multi Frequency Instrument)

4 Horns, 32 channels, 4 frequency bands: **(11, 13, 17, 19)** GHz

Angular resolution:  $0.92^\circ$ - $0.63^\circ$

Sensitivity per channel:  
500-600  $\mu\text{K} \cdot \sqrt{\text{s}}$   
Stepping polar modulator (HWP)

Operative since Nov 2012



## QT2 & TFGI

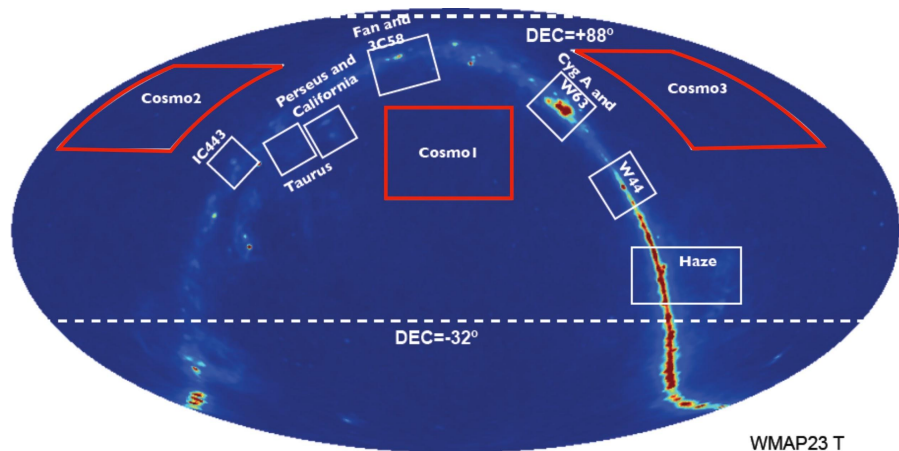
(Thirty and Forty GHz Instrument)  
14 pixels at **30** GHz, 15 pixels at **40** GHz

Angular resolution:  $0.32^\circ$ - $0.26^\circ$

Sensitivity of the full array:  
85-71  $\mu\text{K} \cdot \sqrt{\text{s}}$

In commissioning phase

# OBSERVATIONS



## 3 Cosmological regions

3.000 deg<sup>2</sup>

Expected sensitivity after 1 year:

10  $\mu\text{K}/1^\circ\text{beam}$  with MFI

1  $\mu\text{K}/1^\circ\text{beam}$  with TFGI

Raster scans

Goal: CMB B-modes,  $r \sim 0.05$  after 3 years of TFGI data

## Wide survey

20.000 deg<sup>2</sup>

$\sim 1$  year in nominal mode

Sensitivities in Q,U:

$\approx 55 \mu\text{K}/1^\circ\text{beam}$  @ 11, 13 GHz

$\approx 40 \mu\text{K}/1^\circ\text{beam}$  @ 17, 19 GHz

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## Galactic regions (IC443, Taurus, Perseus, Fan, Cygnus, W44, Haze)

$\sim 100 \text{ deg}^2$

30-40  $\mu\text{K}/1^\circ\text{beam}$  with MFI

Raster scans

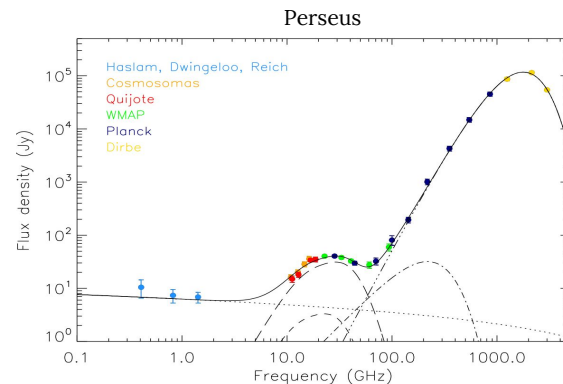
Goal: radio foregrounds characterization (Synchrotron and Anomalous Microwave Emission (AME))

## QUIJOTE scientific results:

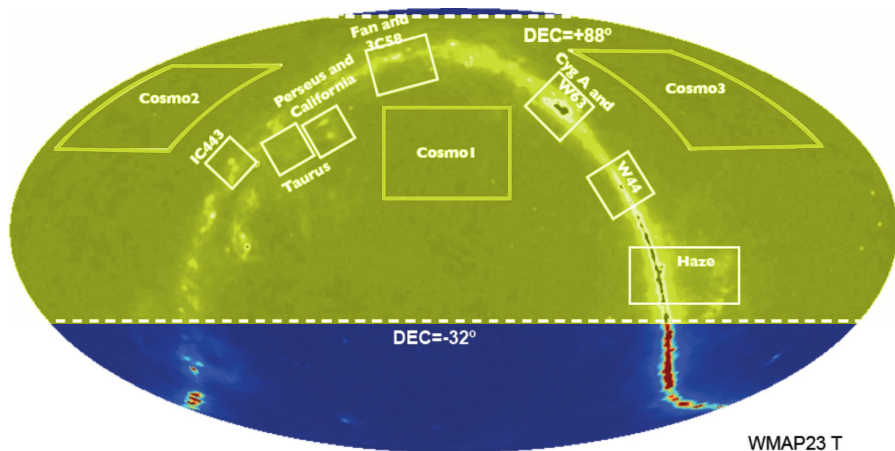
★ Perseus molecular complex: Génova-Santos et al. (2015)

★ W44 supernova remnant, W43 and W47 molecular complexes: Génova-Santos et al. (2017)

★ Taurus molecular cloud and L1527: Poidevin et al. (2018)



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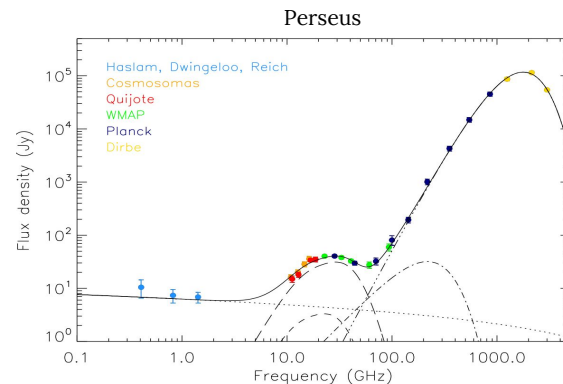
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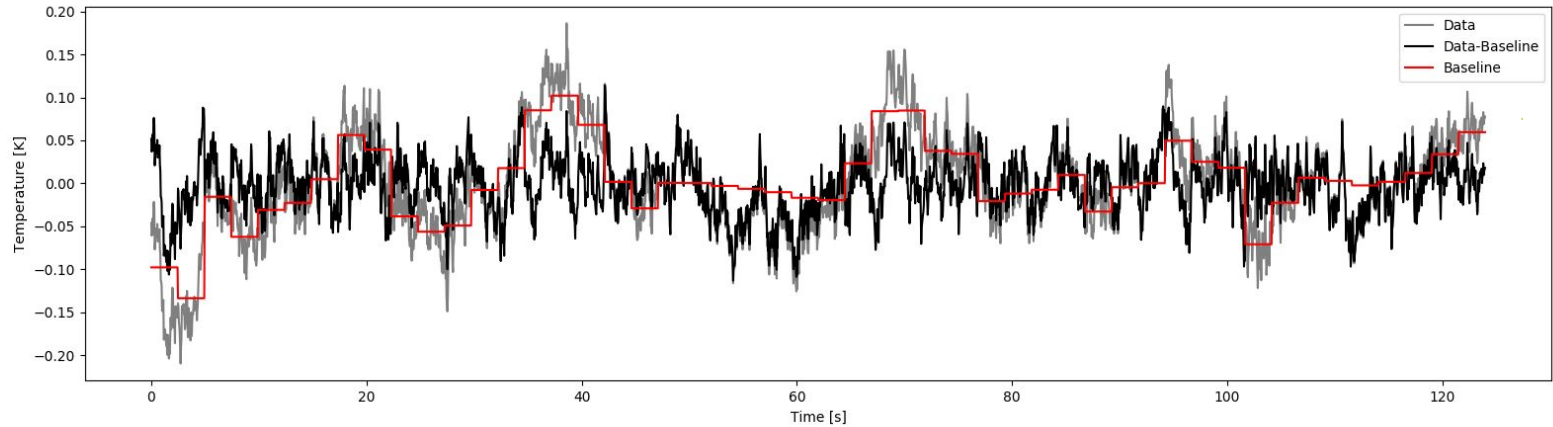
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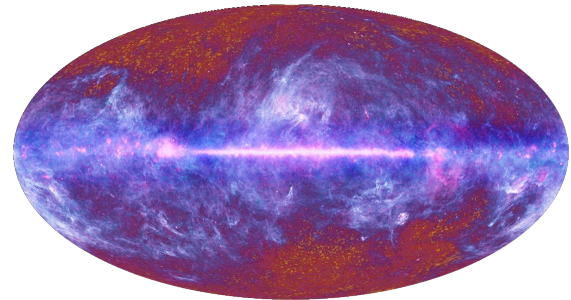


# MAP-MAKING



Destriper + fitting templates:

- Atmosphere
- CMB dipole

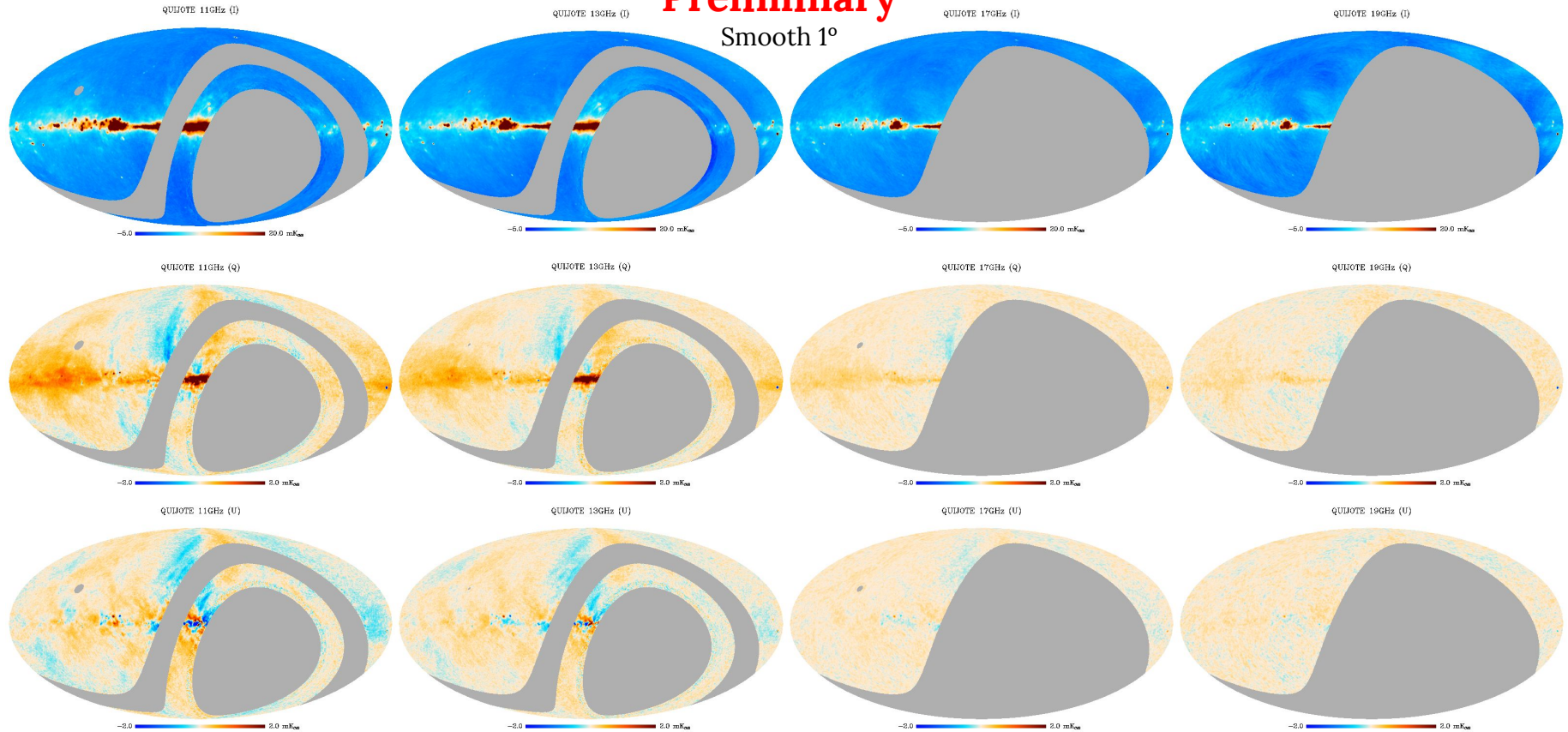


Guidi et al. (in prep.)

# QUIJOTE wide-survey maps @ (11,13,17,19)GHz

**Preliminary**

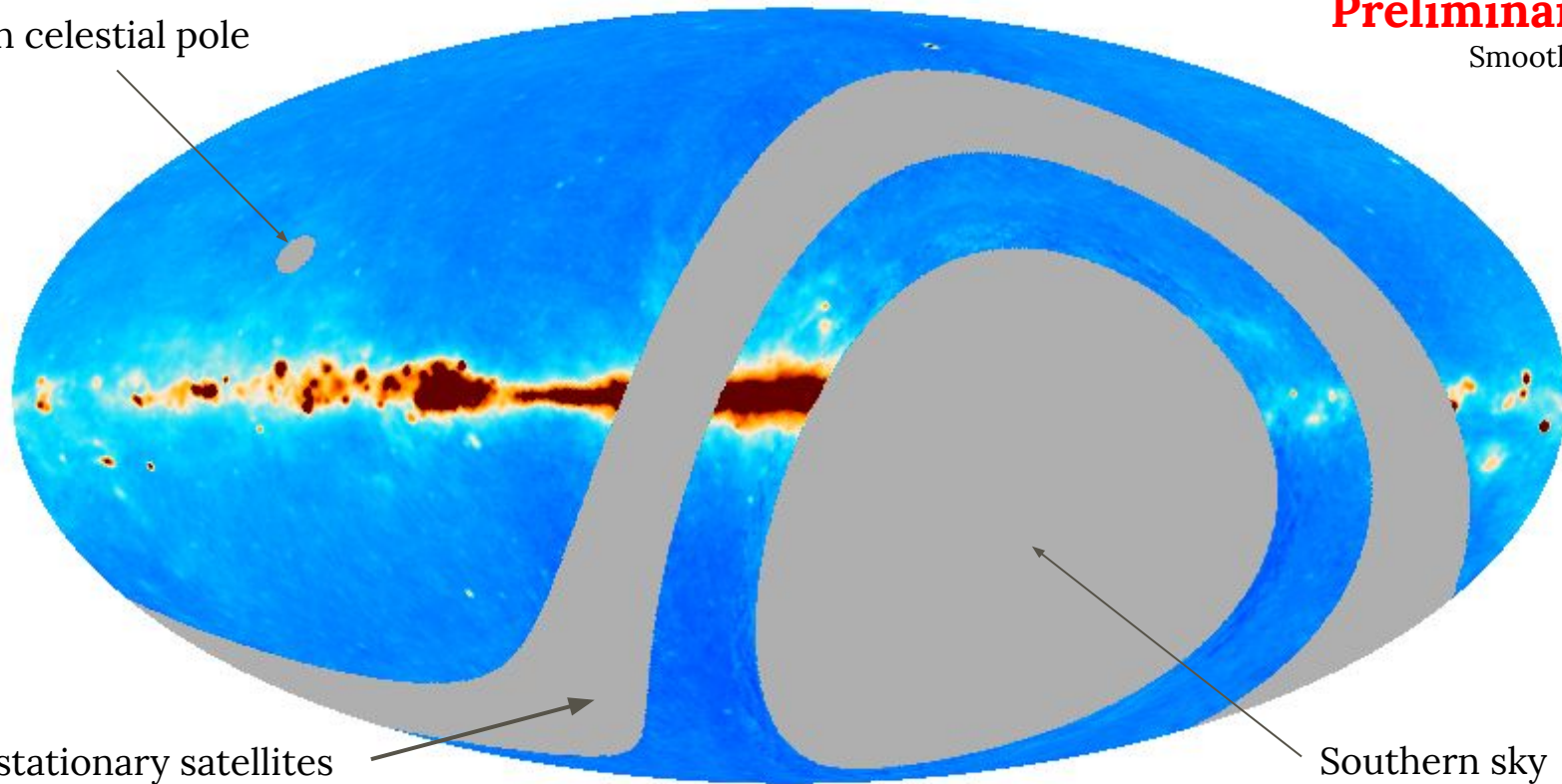
Smooth 1°



QUIJOTE 11GHz (I)

**Preliminary**  
Smooth 1°

North celestial pole



Geostationary satellites

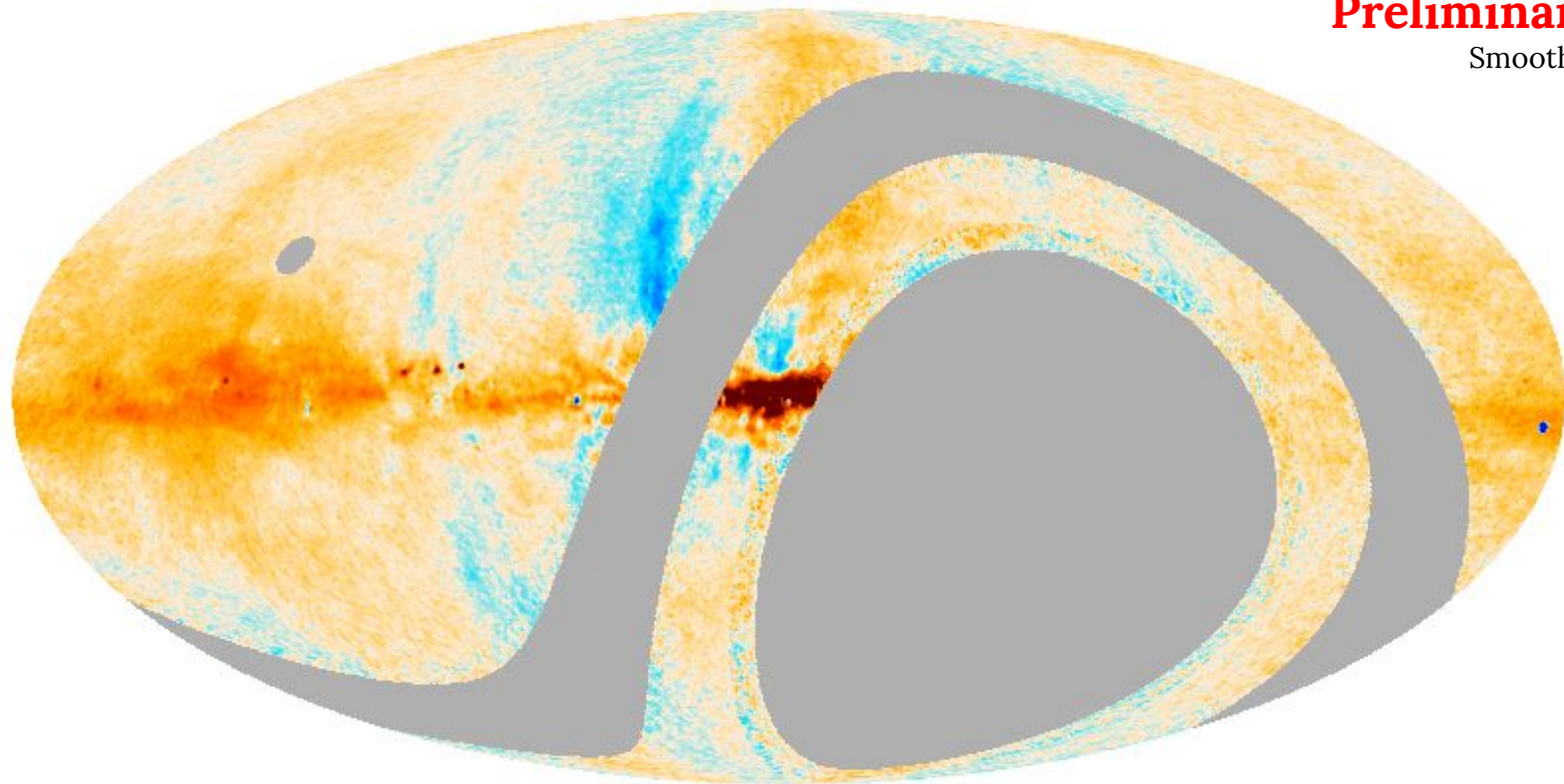
Southern sky



QUIJOTE 11GHz (Q)

**Preliminary**

Smooth 1°

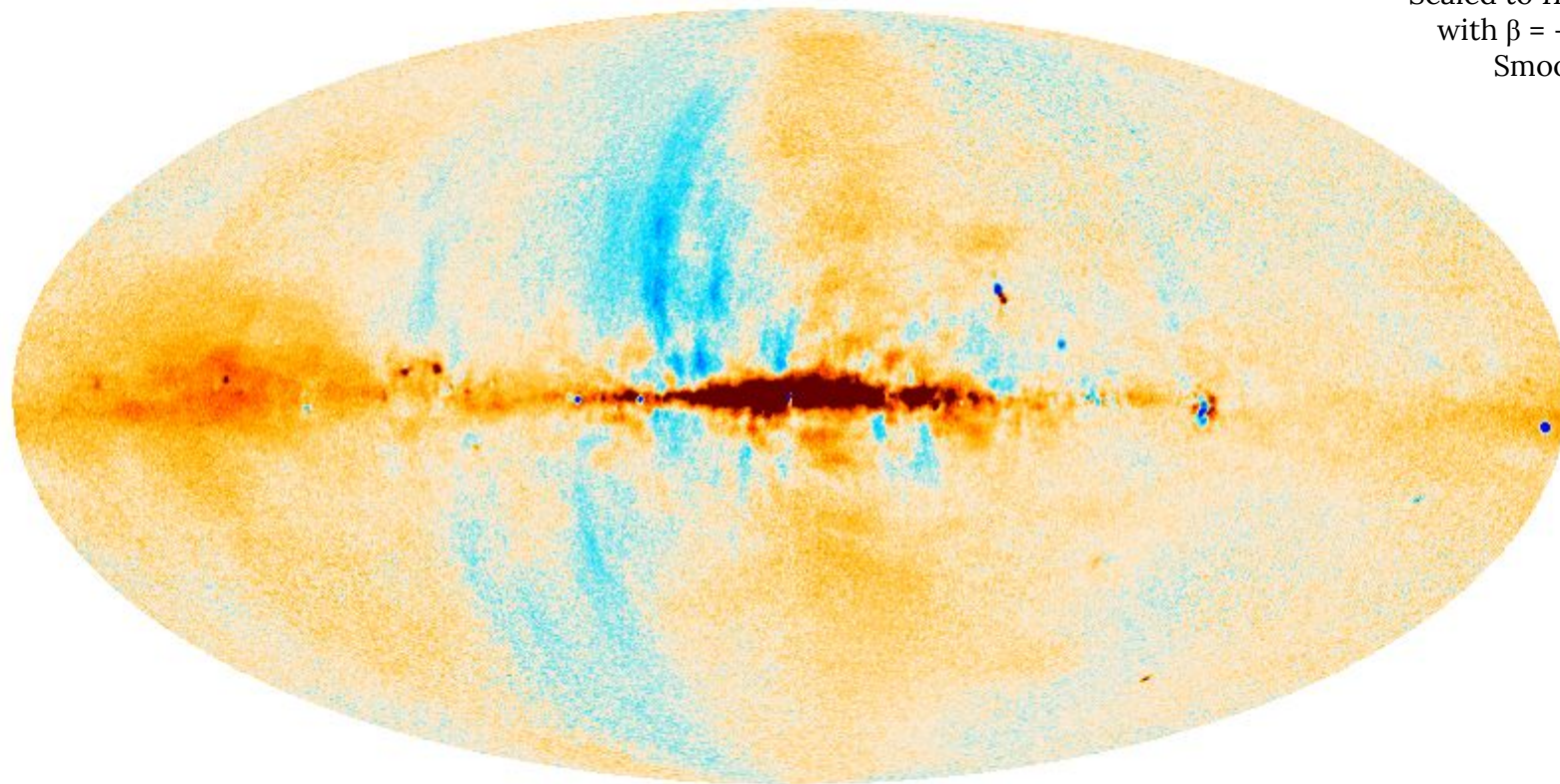


-2.0  2.0 mK<sub>QMB</sub>



WMAP 23GHz (Q)

Scaled to 11 GHz  
with  $\beta = -3.00$   
Smooth  $1^\circ$

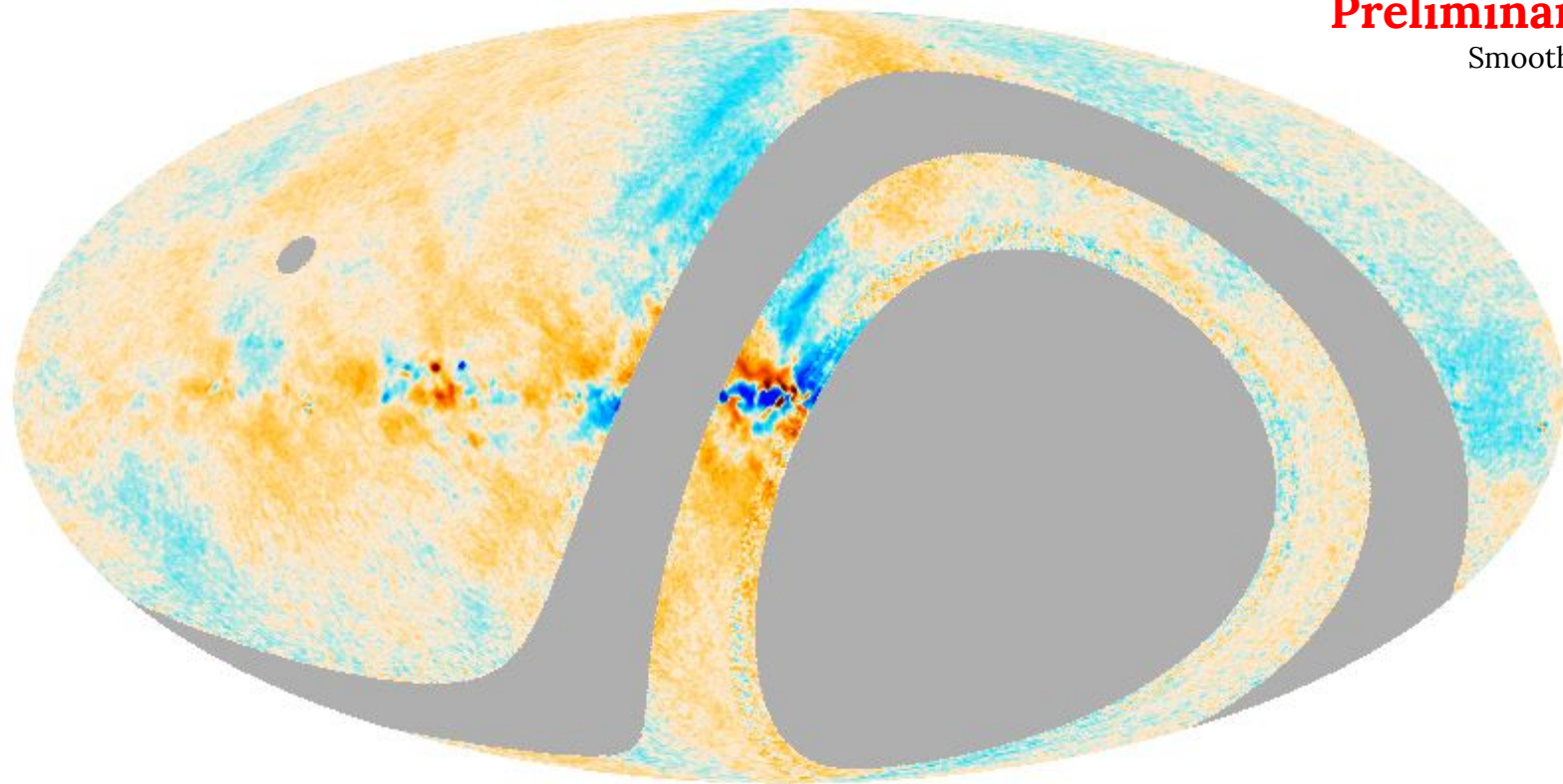


-0.22  0.22 mK

QUIJOTE 11GHz (U)

**Preliminary**

Smooth 1°

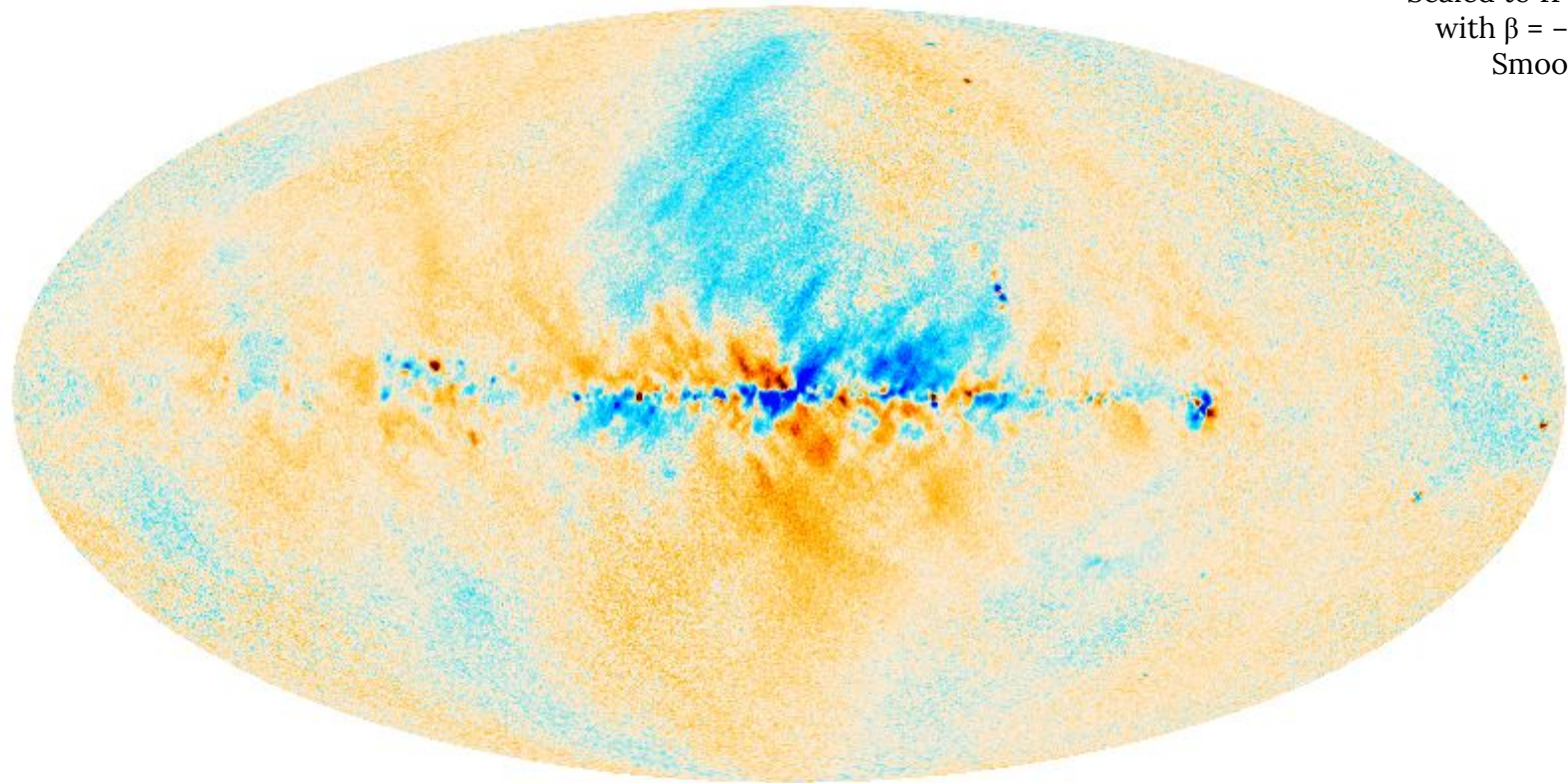


-2.0  2.0 mK<sub>CMB</sub>

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WMAP 23GHz (U)

Scaled to 11 GHz  
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-0.22 0.22 mK

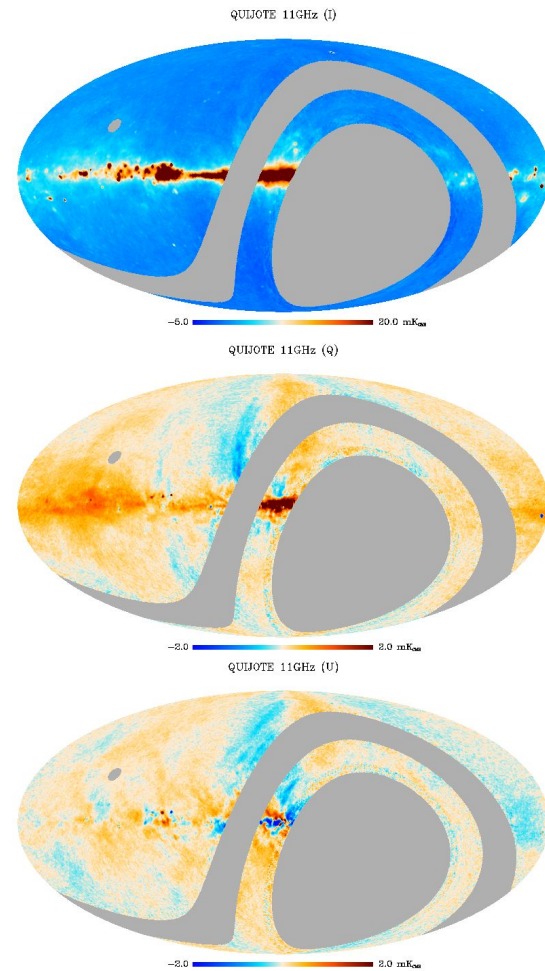
Federica Guidi - MFC 2019

# SCIENCE WITH THE MAPS

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

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

- A northern sky survey at 10-20GHz with the Multi-Frequency Instrument (Rubiño-Martín et al. (in prep)).
- Component separation in intensity with the QUIJOTE-MFI wide survey (Casaponsa et al. (in prep)).
- Component separation in polarization with the QUIJOTE-MFI wide survey (Casaponsa et al. (in prep)).
- Polarised synchrotron emission at the power spectrum level in the MFI wide survey (Vansyngel et al. (in prep)).
- Radiosources in the QUIJOTE-MFI wide survey (Herranz et al. (in prep)).
- Galactic AME sources in the MFI wide survey (Poidevin et al. (in prep)).
- The FAN region as seen by QUIJOTE-MFI (Ruiz-Granados et al. (in prep)).
- The North Galactic Spur as seen by QUIJOTE-MFI (Watson et al. (in prep)).
- W49, W51 and IC443 SNRs as seen by QUIJOTE (Tramonte et al. (in prep)).
- AME in Lambda Orionis (Cepeda-Arroita et al. (in prep))



# SCIENCE WITH THE MAPS:

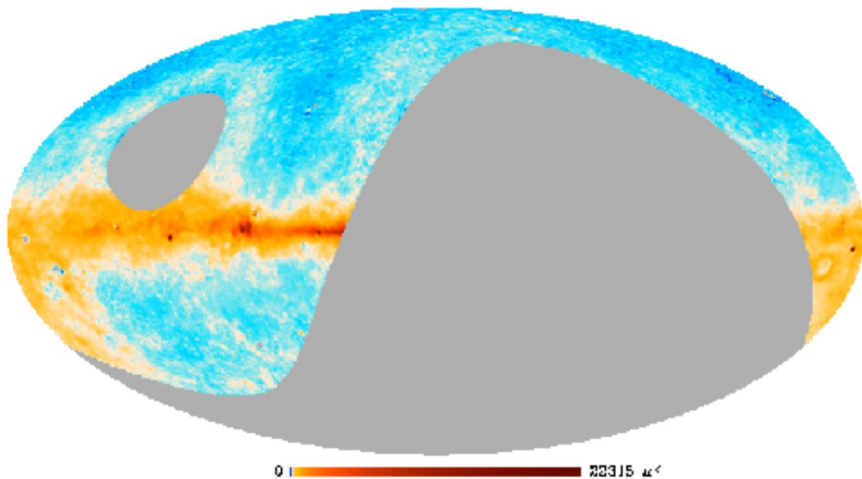
**Preliminary**

Casaponsa et al. (in prep)

## Component separation in intensity and polarization with the QUIJOTE-MFI wide survey

AME Intensity.

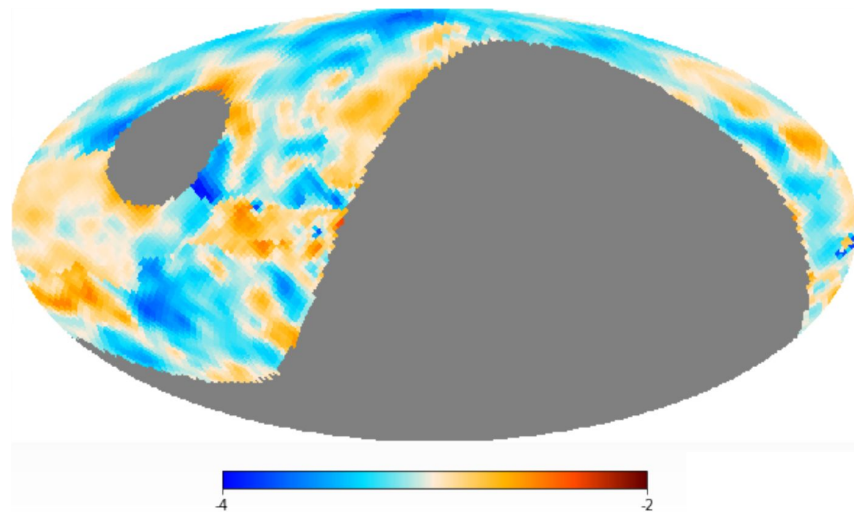
The addition of QUIJOTE-MFI allows a much better separation of free-free and AME. AME is typically ~30% higher than in the original Planck-Commander maps.



Synchrotron spectral index map.

Variability across the sky.

Average:  $\beta = -3.08 \pm 0.22$

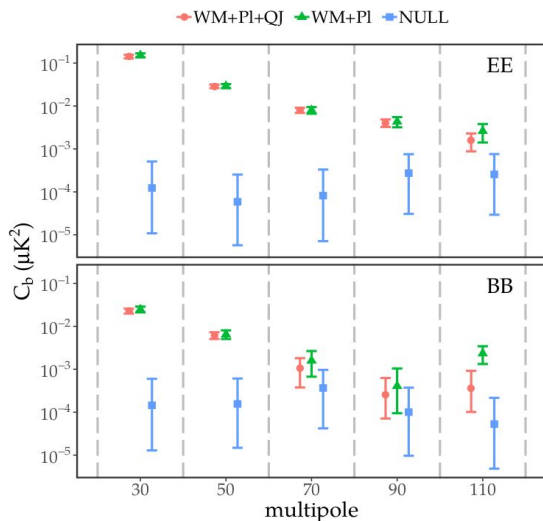


# SCIENCE WITH THE MAPS:

**Preliminary**  
Vansyngel et. al. (in prep)

## Analysis of the polarised synchrotron emission at the power spectrum level in the MFI wide survey

Power spectra of the synchrotron at 23 GHz. for the three different data sets. Top/bottom: EE/BB. The BB spectrum is not reliable above  $l=60$ .



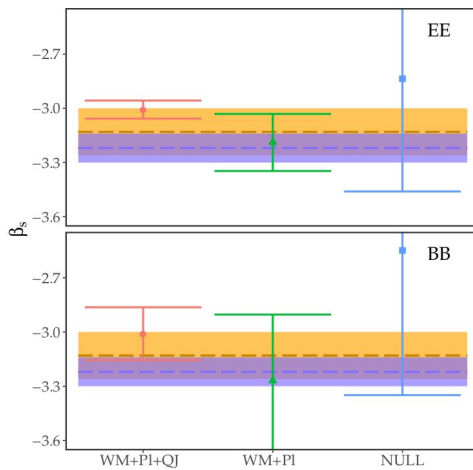
Synchrotron spectral index. The shaded areas represent the Planck and S-PASS values.

QUIJOTE-MFI (North)  $\beta_s = -3.00 \pm 0.05$

S-PASS (South)  $\beta_s = -3.22 \pm 0.08$

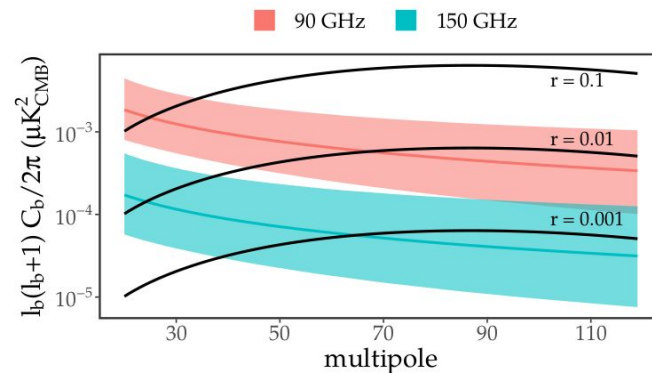
Planck (All-sky)  $\beta_s = -3.13 \pm 0.13$

$\rightarrow$  Spatial variability of  $\beta_s$



Contamination of the CMB at 90 and 150 GHz by the synchrotron B-modes (shaded 2 sigma contours).

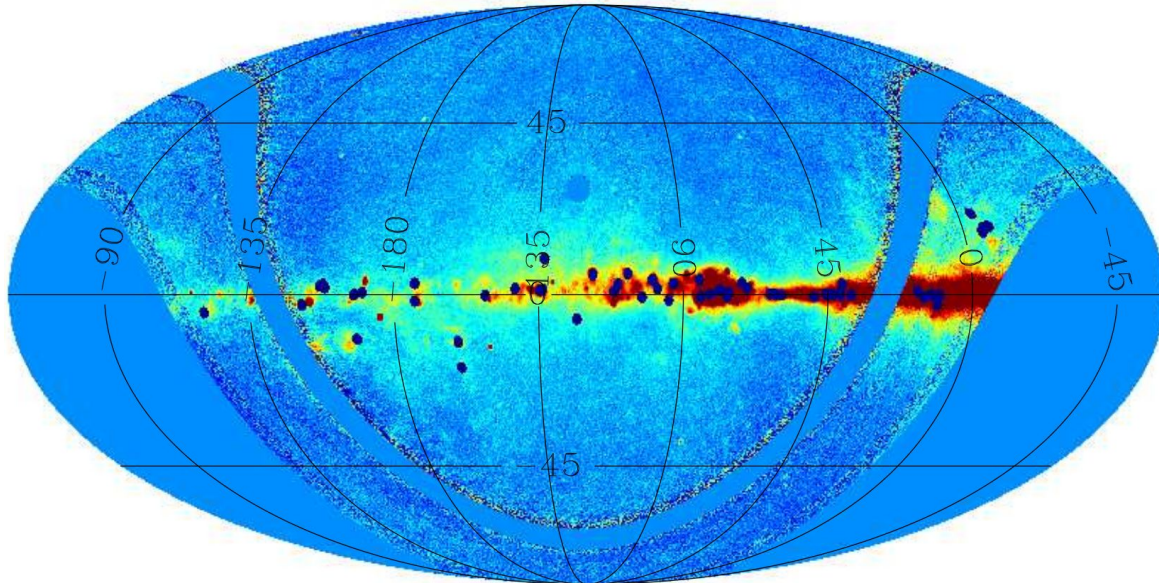
The synchrotron emission is equivalent to  $r = 0.01$  at 90 GHz and to  $r = 0.001$  at 150 GHz.



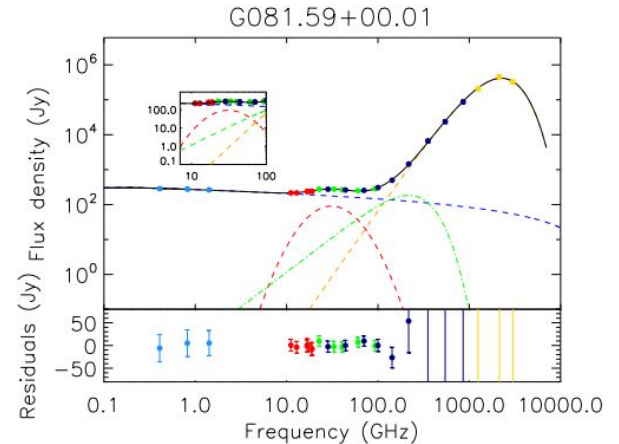
# SCIENCE WITH THE MAPS:

- ★ Radiosources in the QUIJOTE-MFI wide survey (Herranz et al. (in prep))
- ★ Galactic AME sources in the MFI wide survey (Poidevin et. al. (in prep))

AME Sources Location Map



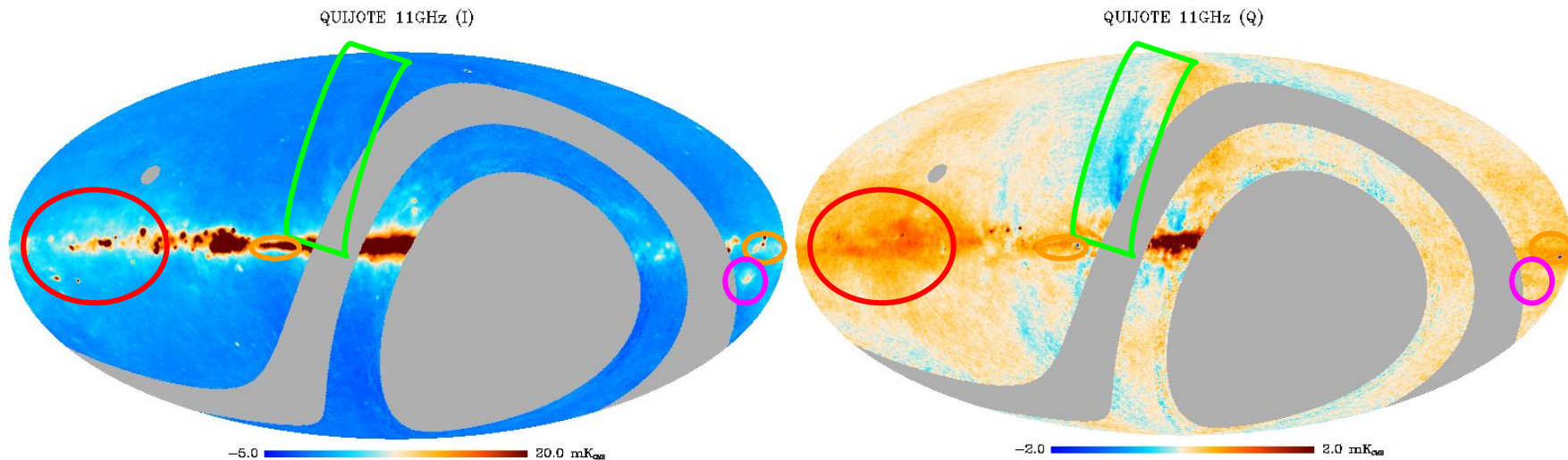
**Preliminary**



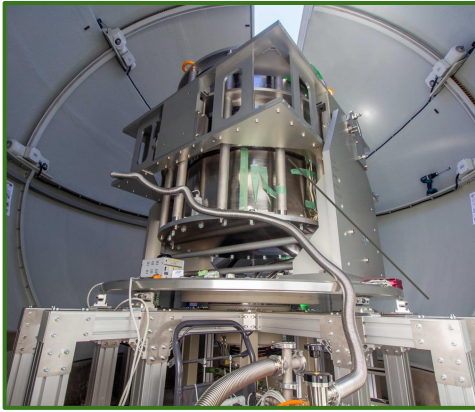
# SCIENCE WITH THE MAPS:

Study of specific regions:

- ★ The **FAN** region as seen by QUIJOTE-MFI (Ruiz-Granados et al. (in prep)).
- ★ The **North Galactic Spur** as seen by QUIJOTE-MFI (Watson et al. (in prep)).
- ★ **W49, W51 and IC443** SNRs as seen by QUIJOTE (Tramonte et al. (in prep)).
- ★ AME in **Lambda Orionis** (Cepeda-Arroita et al. (in prep))







# GroundBIRD and STRIP

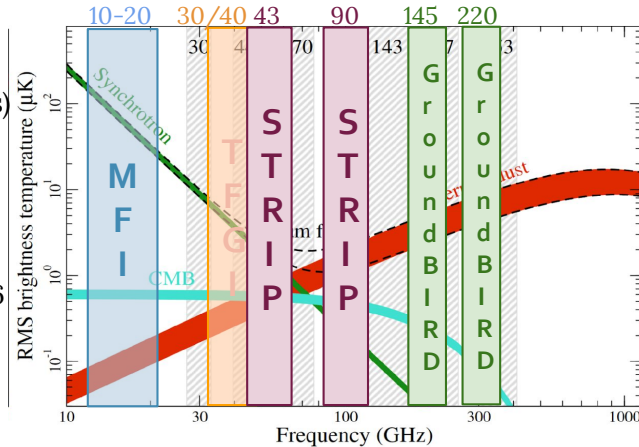
Complementary to QUIJOTE:

- same location (Teide Observatory)
- similar sky coverage
- similar angular resolution
- expanding QUIJOTE frequency coverage



## GroundBIRD:

- Installation in progress
- Location: Teide Observatory
- Operation plan: 3 years (2019-2021)
- 145 GHz (660 KIDs) and 220 GHz (224 KIDs)
- Expected sensitivity: 300  $\mu\text{K}\cdot\text{sqrt(s)}$ /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 of 20 rpm
- 20-deg FOV with angular resolution of 0.6 deg @ 145 GHz
- Aims: reionisation and recombination bumps
- Final goal:  $r=0.01$



## STRIP:

- Planned installation: beginning 2021
- Location: Teide Observatory
- 43 and 90 GHz
- 1.5m cross-Dragone telescope (Oxford University)
- 25% sky coverage
- Beam FWHM = 0.5 deg
- Expected full-array sensitivity:  $\sim 43 \mu\text{K}\cdot\text{sqrt(s)}$  @ 43 GHz and  $137 \mu\text{K}\cdot\text{sqrt(s)}$  @ 90 GHz
- LSPE/SWIPE (balloon from Svalbard) is based on bolometers at 140, 220 and 240 GHz
- Final goal:  $r=0.01$

# Summary

- ★ QUIJOTE maps of the Northern sky at 11, 13, 17, 19 GHz (publicly available soon)
- ★ Characterization of low frequency foregrounds for CMB B-modes studies
- ★ Synchrotron  $\beta_s = -3.00 \pm 0.05$ , spatial variability
- ★ Systematic study of AME sources and of diffuse AME

## Future:

- ★ TFGI for CMB B-modes detection up to  $r \sim 0.05$
- ★ Overlap with new experiments at higher frequencies (GroundBIRD, LSPE/STRIP)

