Wide-survey of the QUIJOTE CMB experiment

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16 November 2021 @ CMB-France #2

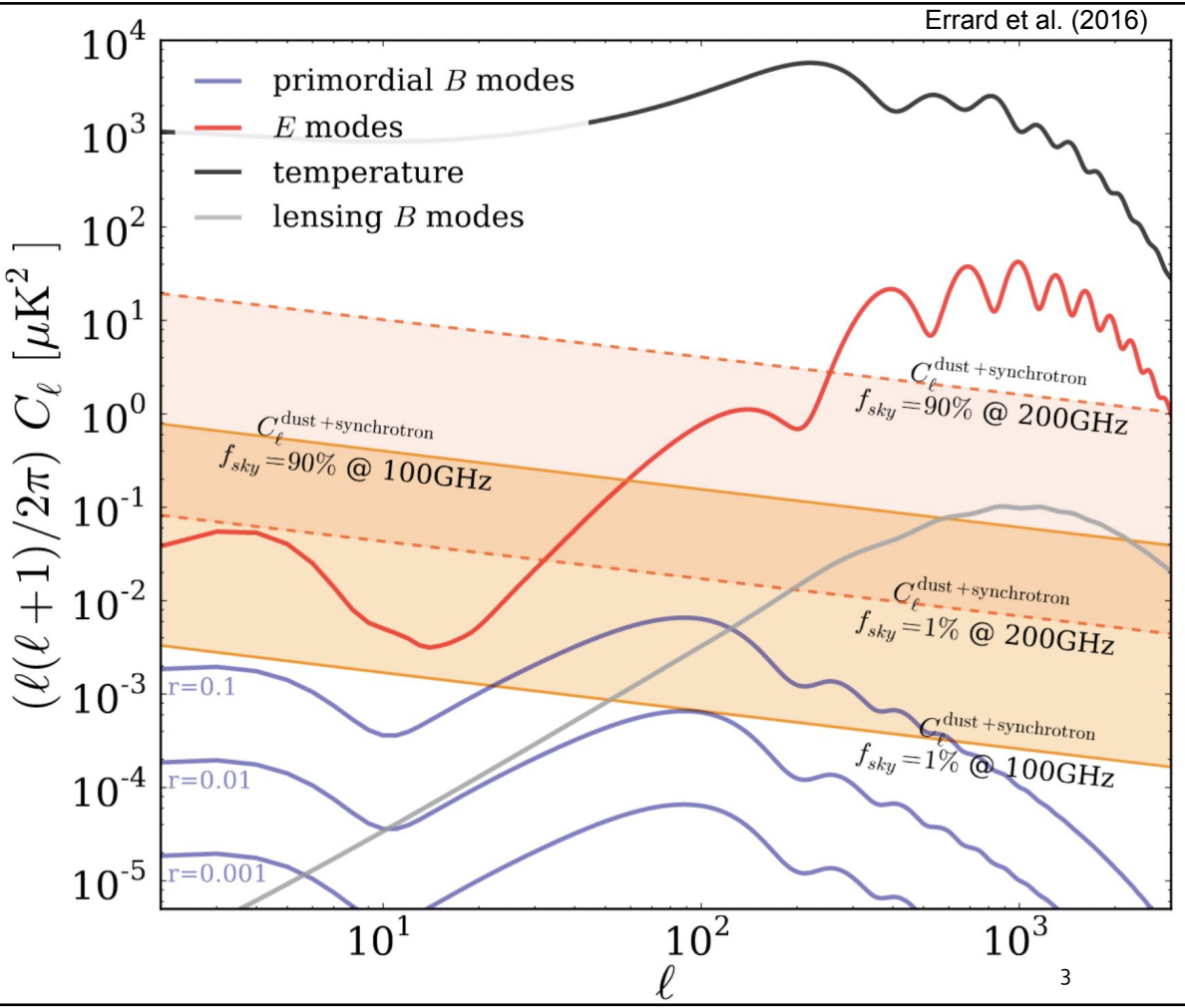
Outline

- Context: low frequency CMB foregrounds
- The QUIJOTE experiment
- Wide-survey maps (MFI 10-20 GHz)
- Science with the maps

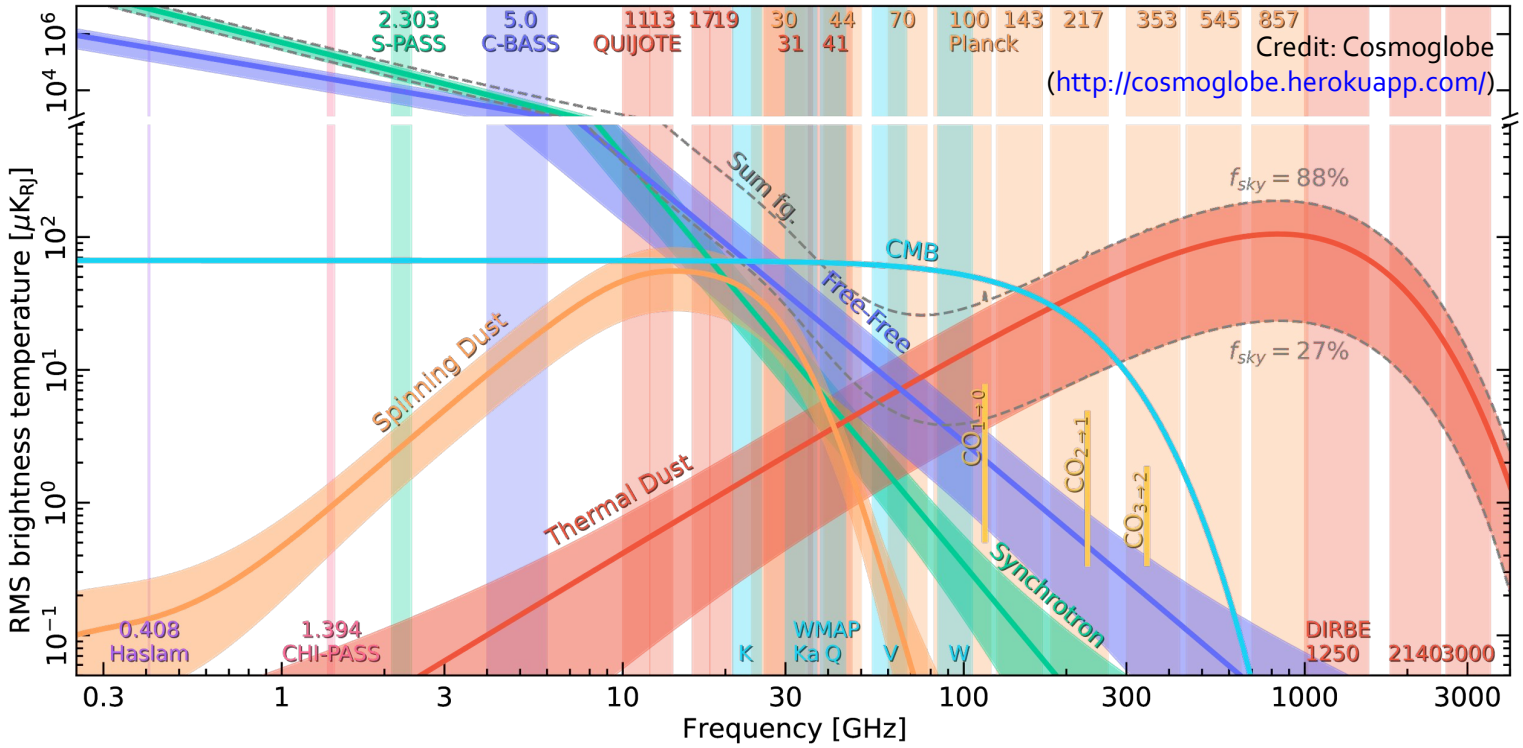
Galactic foregrounds

Primordial B-modes are fainter than polarized Galactic foregrounds at:

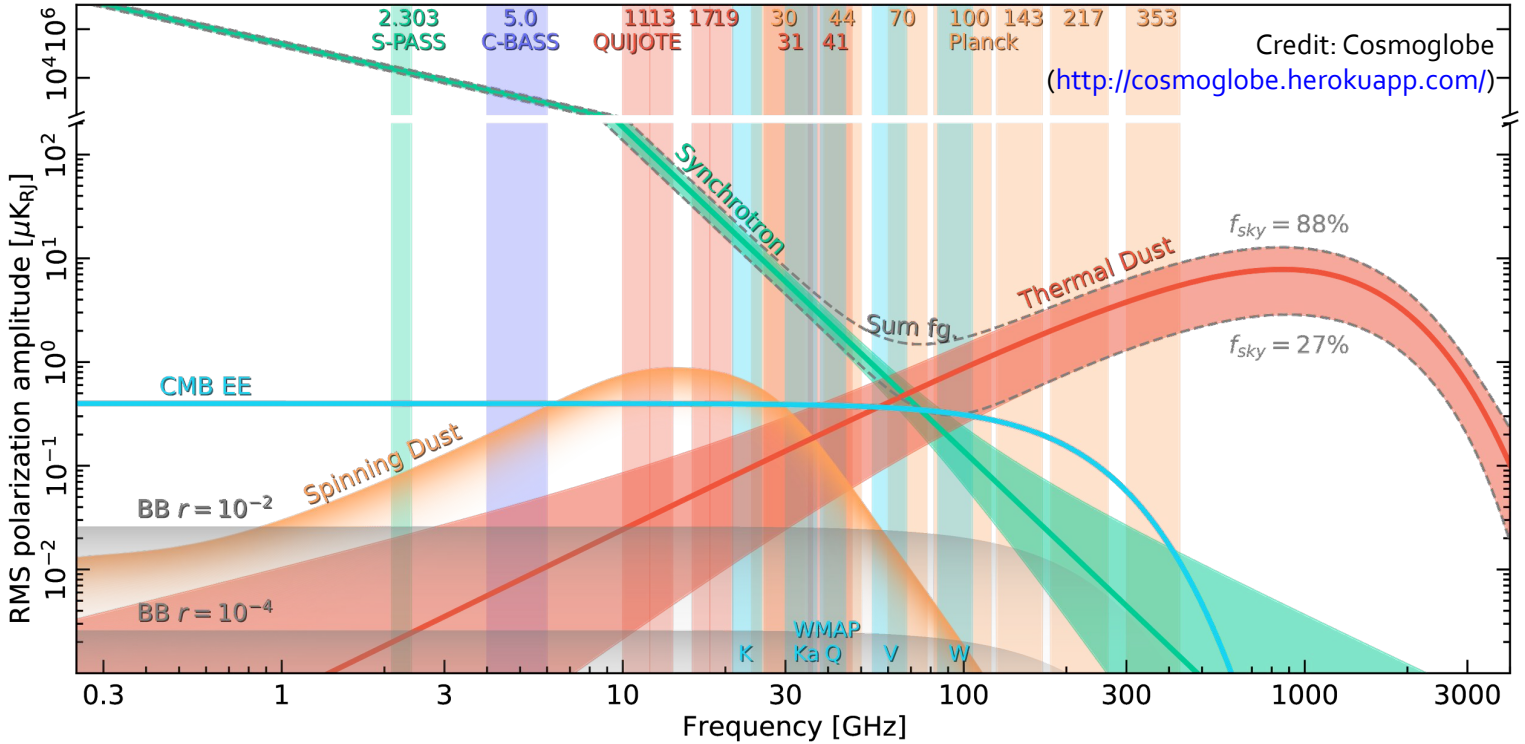
- all multipoles
- all frequencies



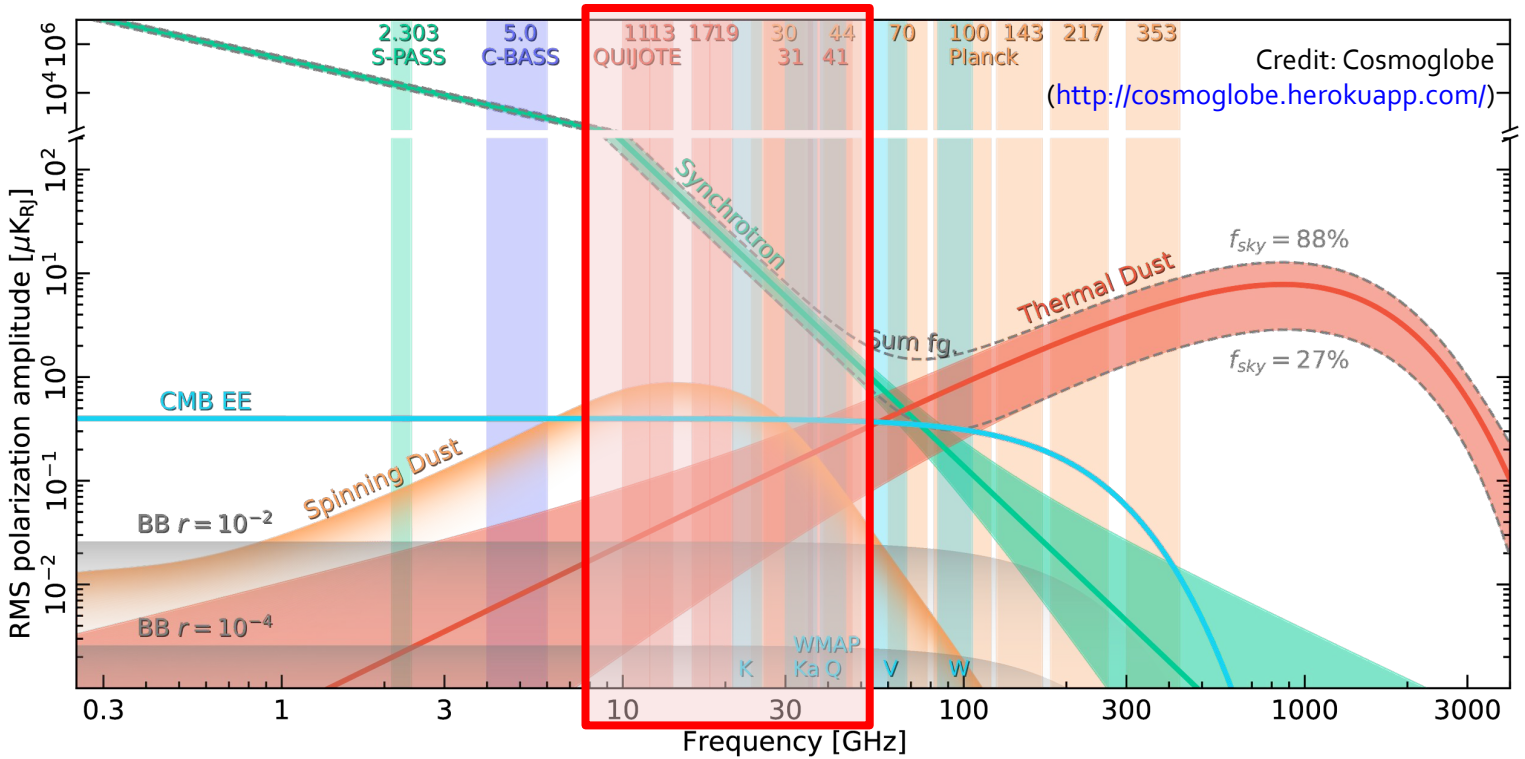
Galactic foregrounds in intensity



Galactic foregrounds in polarization

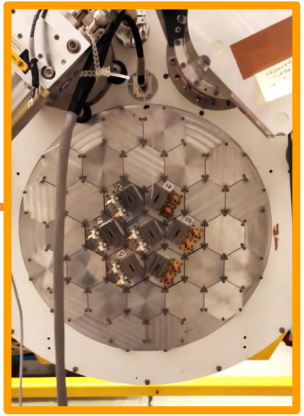


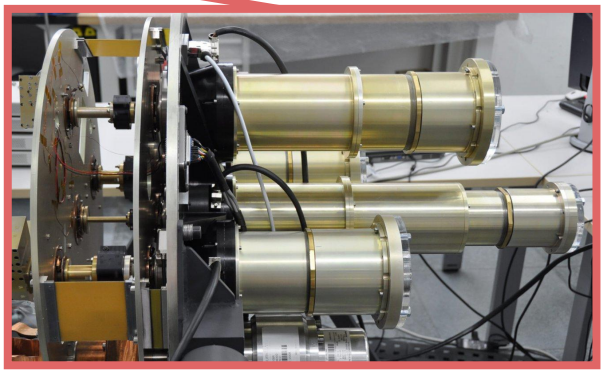
Galactic foregrounds in polarization



QUI-JOint-TEnerife experiment: MFI and FTGI

QT2 &
TGI and **FGI**
30GHz 40GHz





QT1 & MFI (Multi Frequency Instrument)

- 4 Horns, 32 channels, 4 frequency bands: (**11, 13, 17, 19**) GHz
- Angular resolution: 0.92°-0.63°
- Sensitivity per channel, per horn: 500-600 μK sqrt(s)
- Stepping polar modulator (HWP)

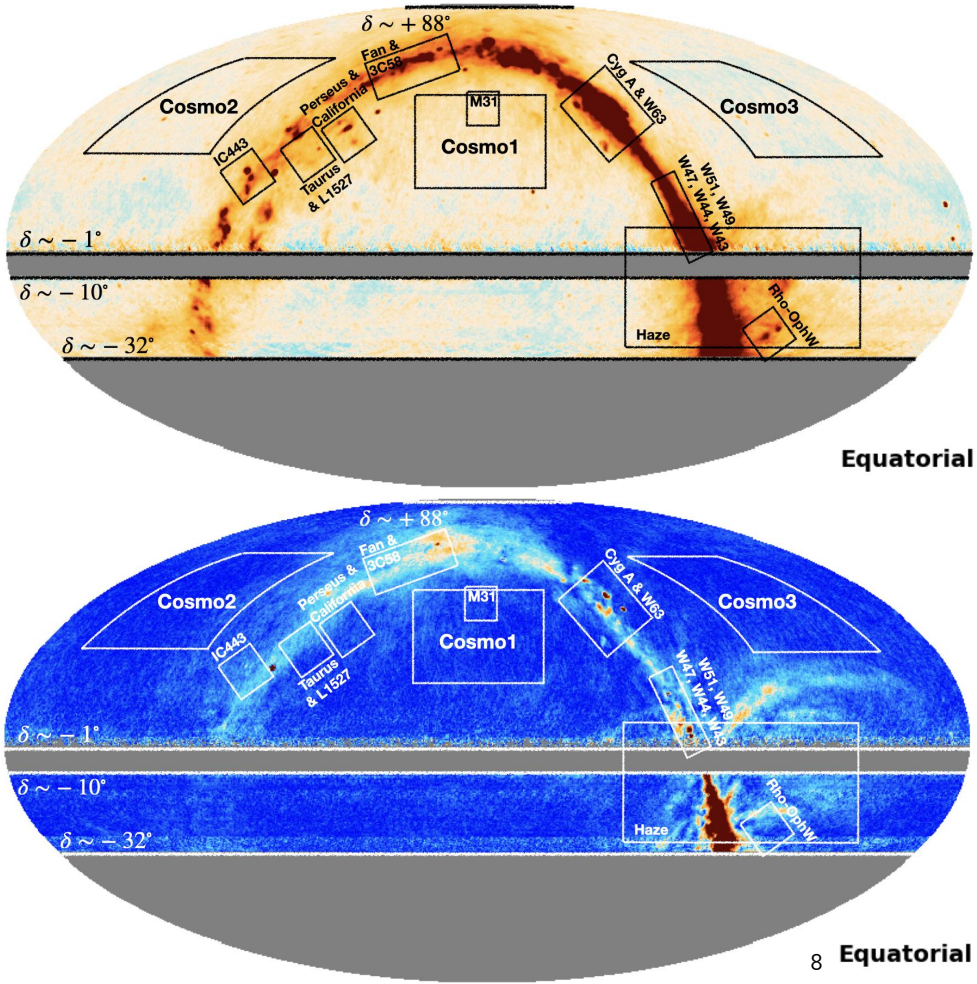
Operative: Nov 2012 - Nov 2018, from the Teide observatory (Tenerife, Spain)

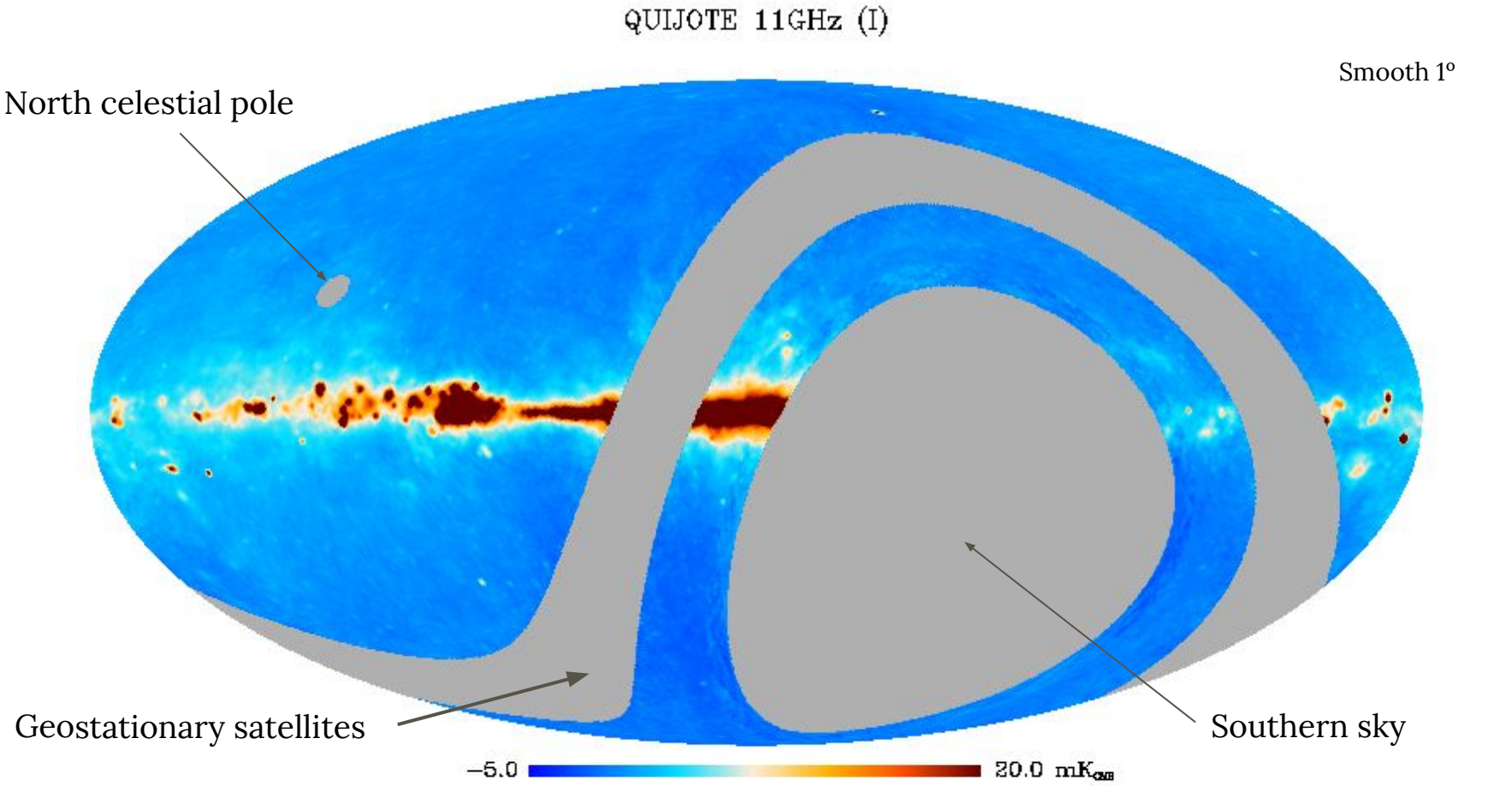
Observations

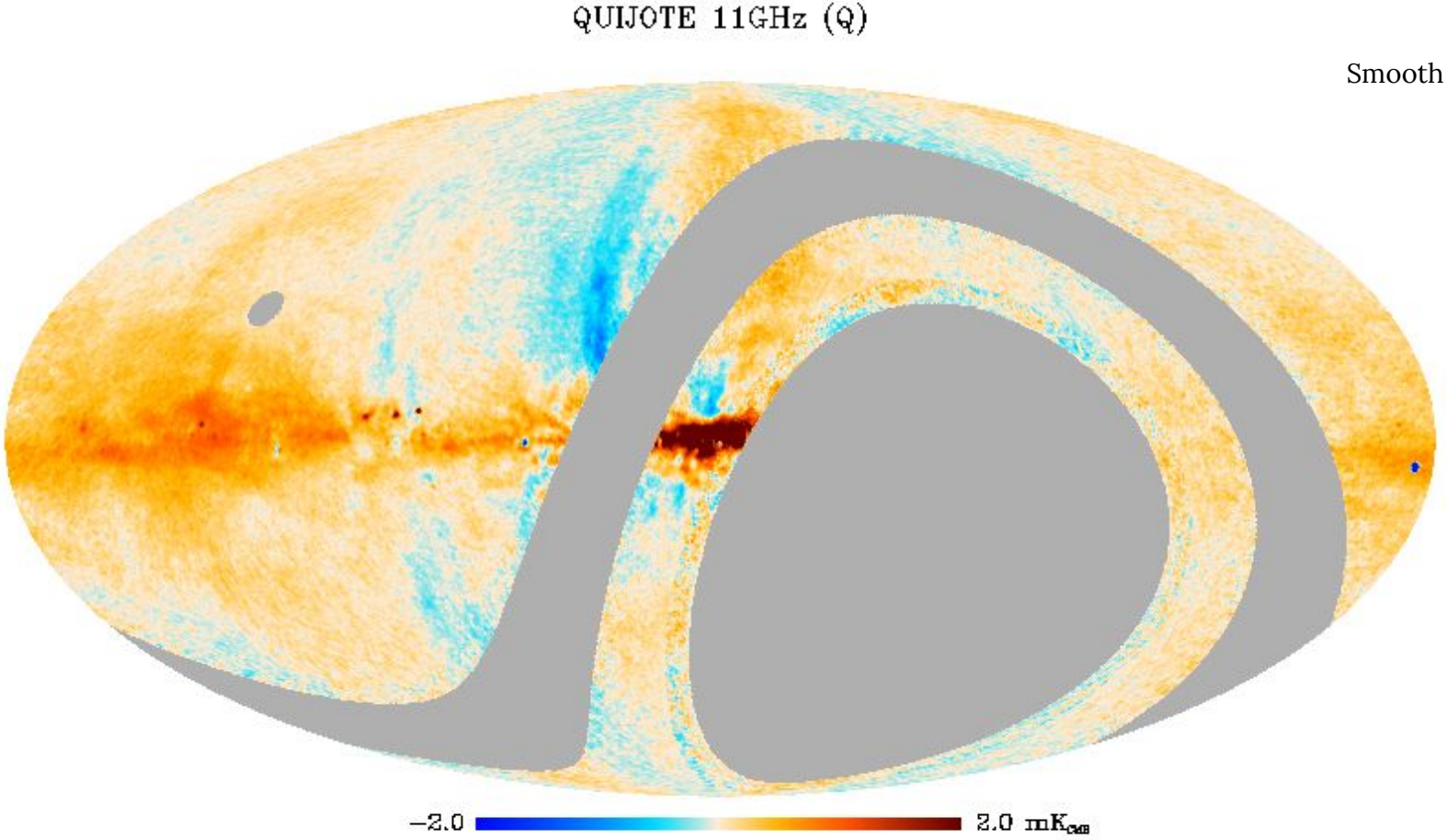
1. **Galactic regions**
   Génova-Santos et al. 2015 (Perseus)
   Génova-Santos et al. 2017 (W44, W43, W47)
   Poidevin et al. (2018) (Taurus, L1527)

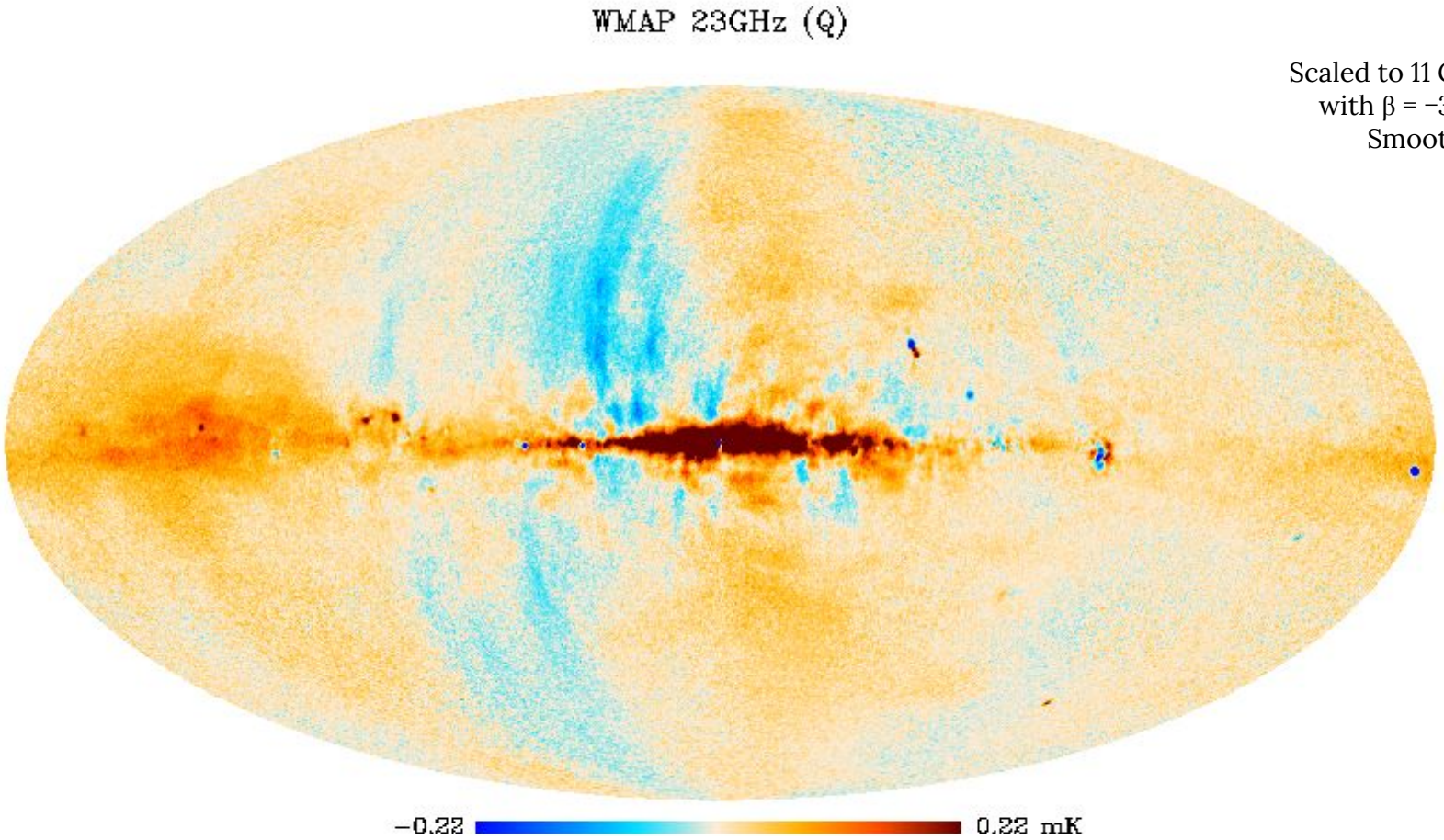
2. **Cosmological fields**
   ≈3 x 1000 deg²
   Expected sensitivity after 1 year:
   10 μK/1°beam with MFI
   1 μK/1°beam with TFGI

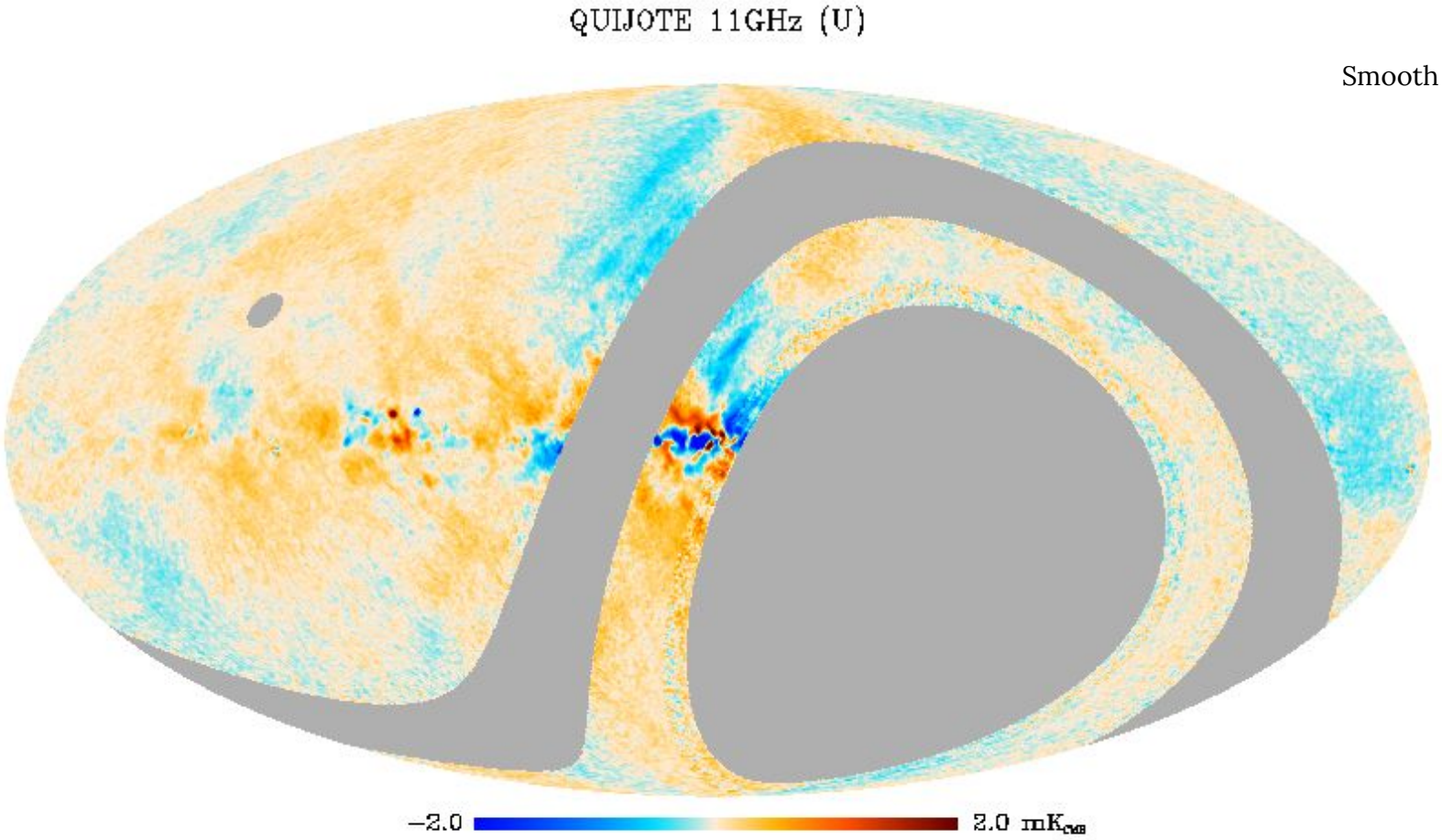
3. **Wide-survey** (nominal)**:**
   Full northern sky
   ≈20.000 deg²
   $-32^{o} \lesssim \delta \lesssim +88^{o}$

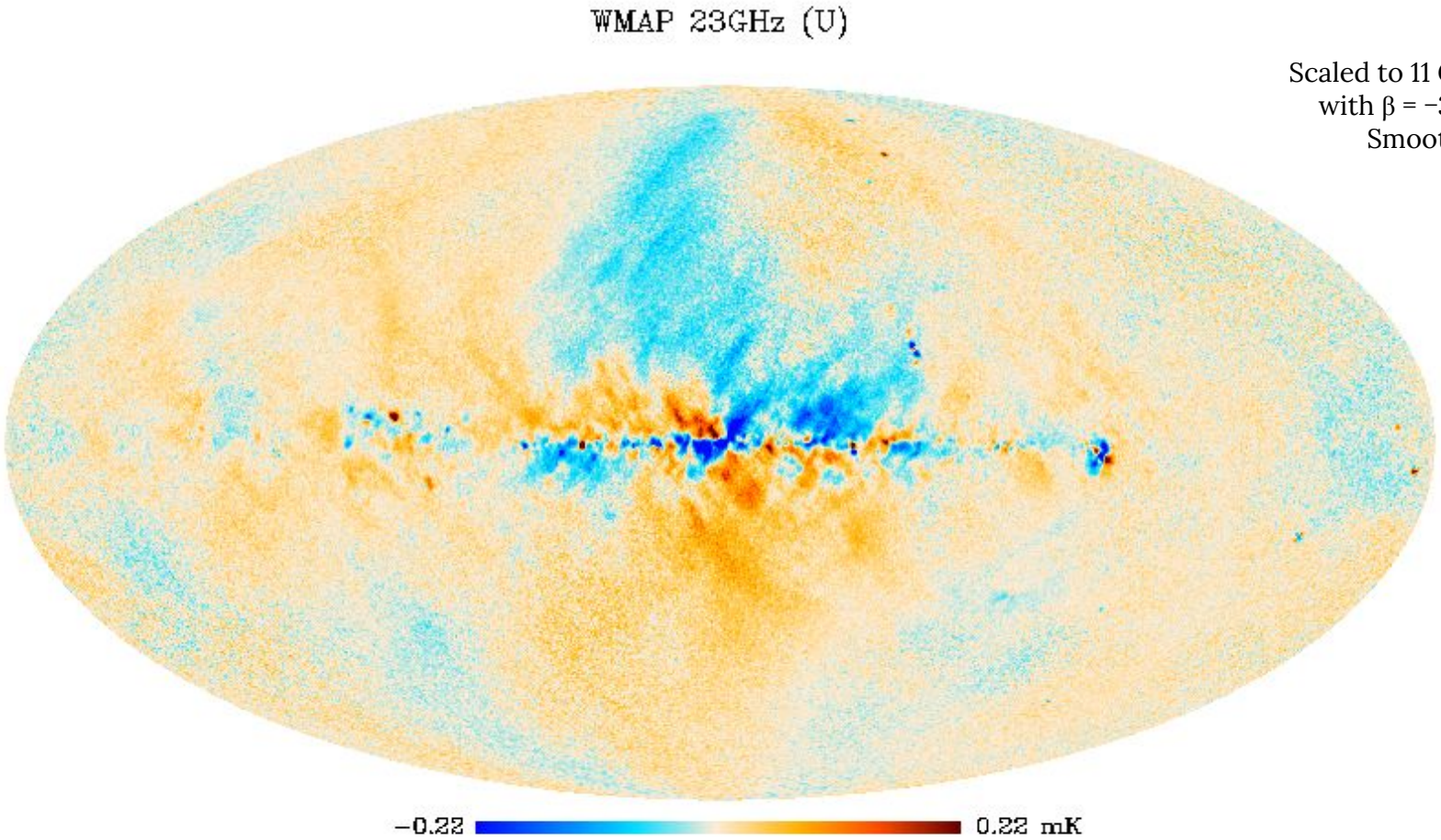



QUIJOTE 11GHz (I)
Smooth 1º
North celestial pole
Geostationary satellites
Southern sky
−5.0
20.0 mK


QUIJOTE 11GHz (Q)
Smooth 1º
−2.0
2.0 mK$_{cmb}$

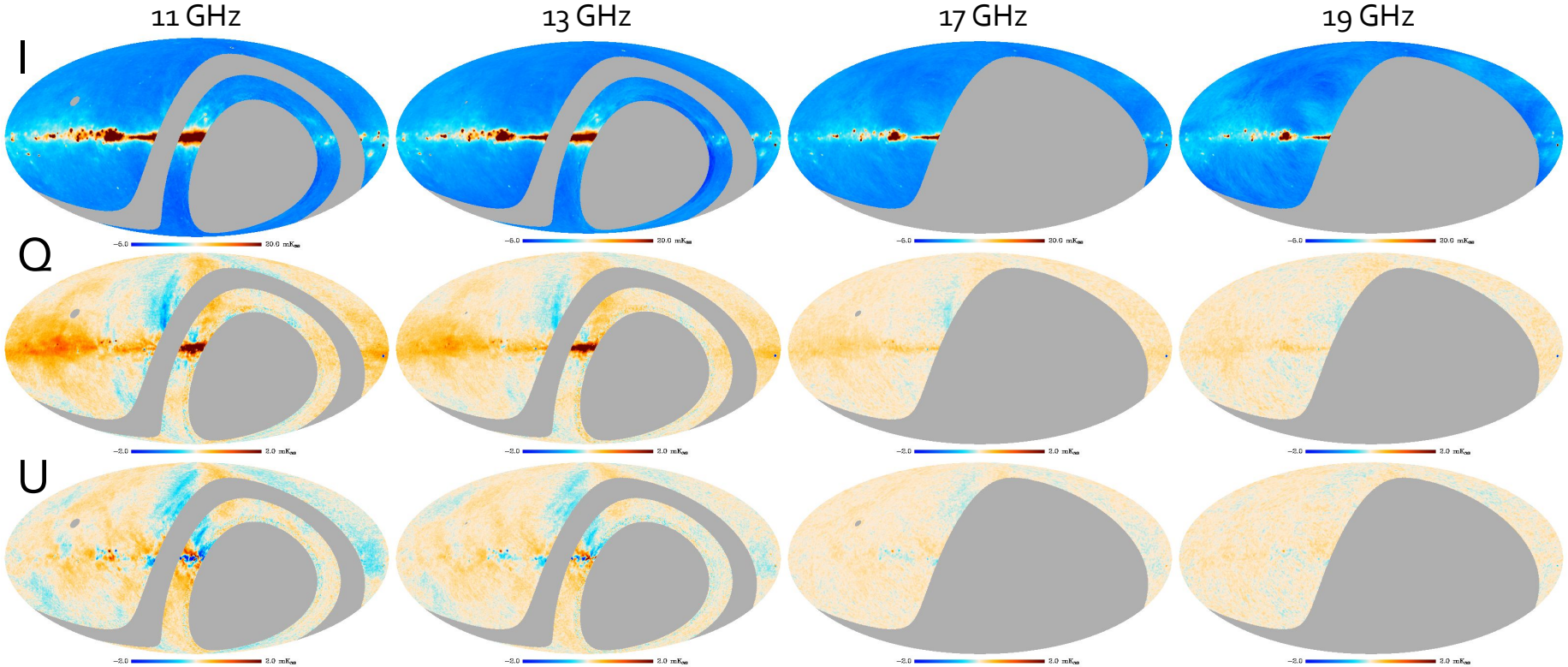

WMAP 23GHz (Q)
Scaled to 11 GHz
with β = −3.00
Smooth 1°
−0.22
0.22 mK


QUIJOTE 11GHz (U)
Smooth 1º
−2.0
2.0 mK$_{CMB}$



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

Wide-survey maps



Noise std: ≈ 100 μK/1° (I); ≈ 40 μK/1° (Q,U)

Upcoming results

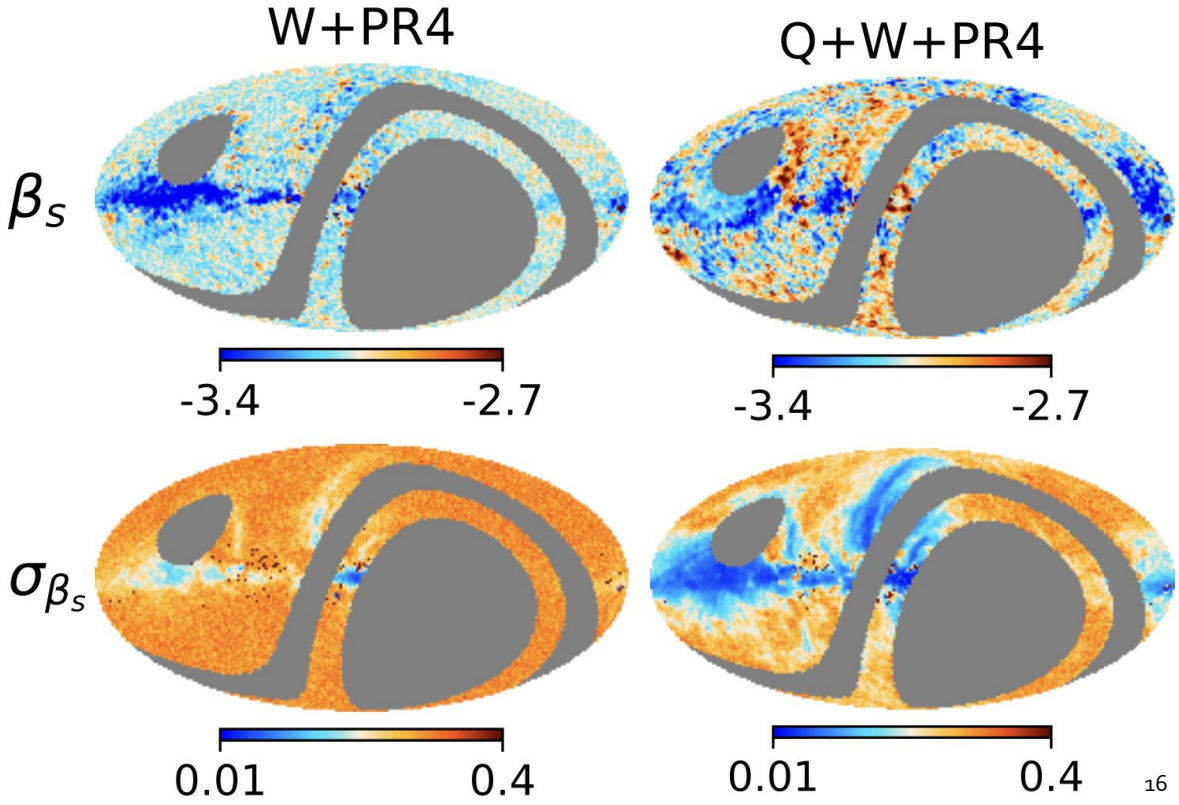
Maps will be publicly available

Papers based on the QUIJOTE wide-survey:

1. **Northern sky survey at 10-20GHz** with QUIJOTE-MFI (Rubiño-Martin et al., in prep.)
2. The **Haze** as seen by QUIJOTE-MFI (Guidi et al. , in prep.)
3. **Pipeline** of QUIJOTE-MFI (Genova Santos et al., in prep.)
4. **Galactic AME sources** in the MFI wide survey (Poidevin et al., in prep.)
5. **AME in the Galactic plane** (Fernández-Torreiro el at., in prep.)
6. **Polarized loops and spurs** as seen by QUIJOTE-MFI (Peel et al, in prep.)
7. **SNRs** as seen by QUIJOTE-MFI (López-Caraballo at al., in prep.)
8. **Polarised synchrotron with power spectra** of the MFI wide survey (Vansyngel et al., in prep.)
9. The **FAN region** as seen by QUIJOTE-MFI (Ruiz-Granados et al., in prep.)
10. **W49, W51 and IC443 SNRs** as seen by QUIJOTE (Tramonte et al., in prep.)
11. **Polarization component separation** with the QUIJOTE-MFI wide survey (De la Hoz et al., in prep.)
12. **Radiosources** in the QUIJOTE-MFI wide survey (Herranz et al., in prep.)
13. The **North Galactic Spur** as seen by QUIJOTE-MFI (Watson et al., in prep.)
14. **AME in Lambda Orionis** (Cepeda-Arroita et al., 2021)

Component separation in polarization

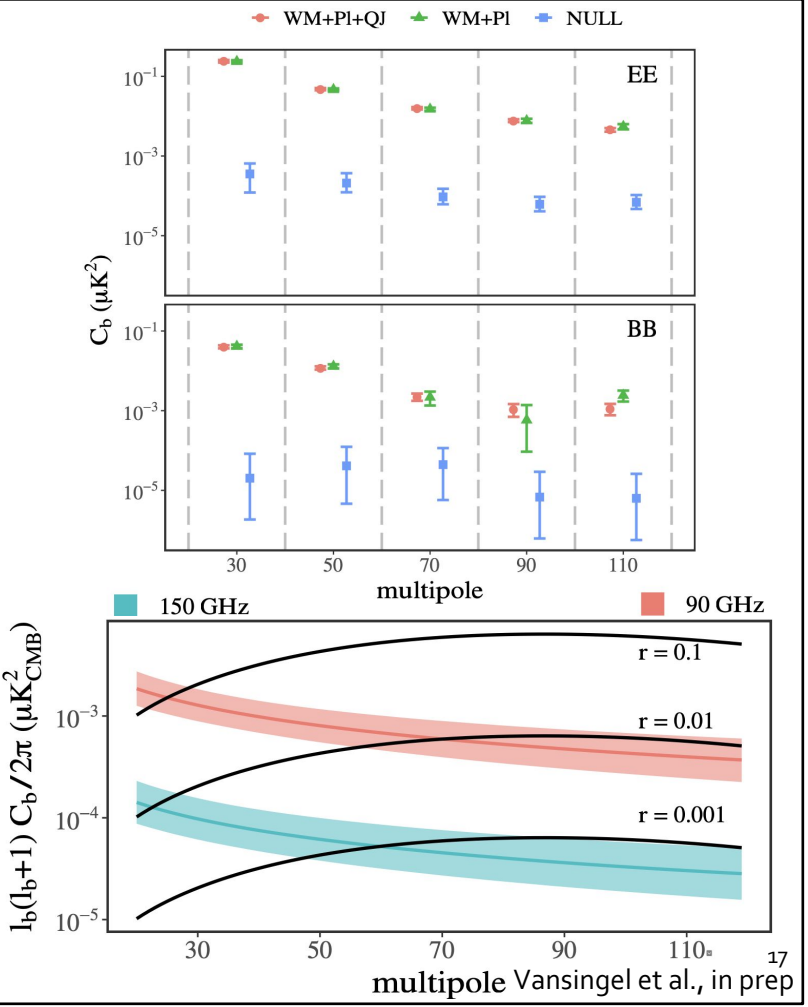
- Improved separation of the synchrotron component
- Other components consistent with previous results (COMMANDER)
- First synchrotron spectral index map
  → Spatial variations of β
- No clear detection of curvature of the synchrotron spectrum



de la Hoz et al., in prep

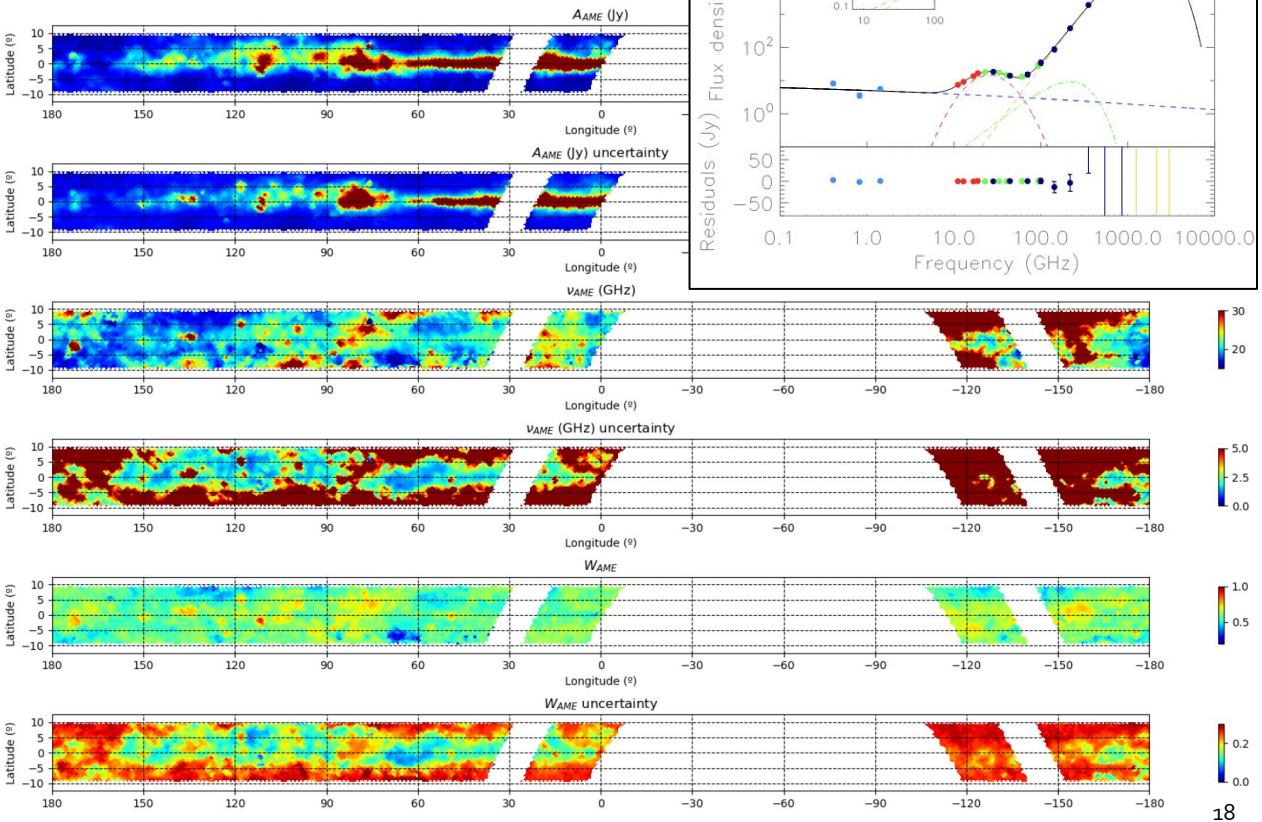
Polarized synchrotron at power spectrum level

- Power spectrum of the synchrotron determined at 23 GHz (EE and BB).
- Global spectral index β = -3.1 ± 0.1, compatible with previous works
- Ratio BB/EE = 0.20±0.05
  A_{BB}/A_{EE} (sync.) < A_{BB}/A_{EE} (dust)=0.5
  (Planck 2018. IV)
- 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 ; r = 0.001 at 150 GHz

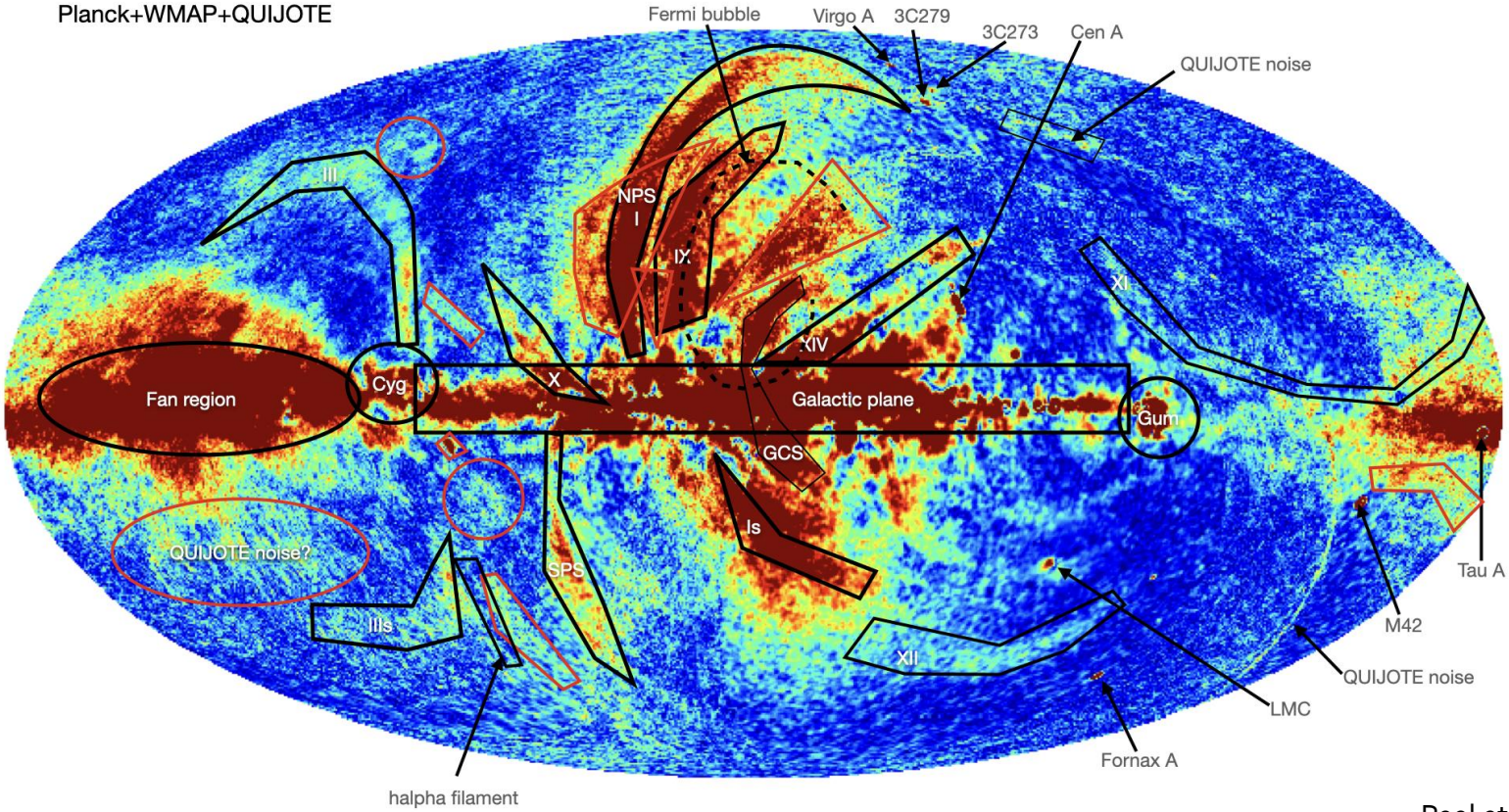


Anomalous Microwave Emission in intensity

- Systematic study of AME compact sources, their SEDs, and parameters correlations (Poidevin et al., in prep.)
- Study of spatial variability of AME parameters in
  - Lambda Orionis (Cepeda-Arroita et al., 2021)
  - Galactic plane (Fernández-Torreiro el at., in prep.)



Polarized loops and spurs as seen by QUIJOTE-MFI



Peel et al., in prep

The Haze

Diffuse intensity microwaves observed in the low frequency maps of:

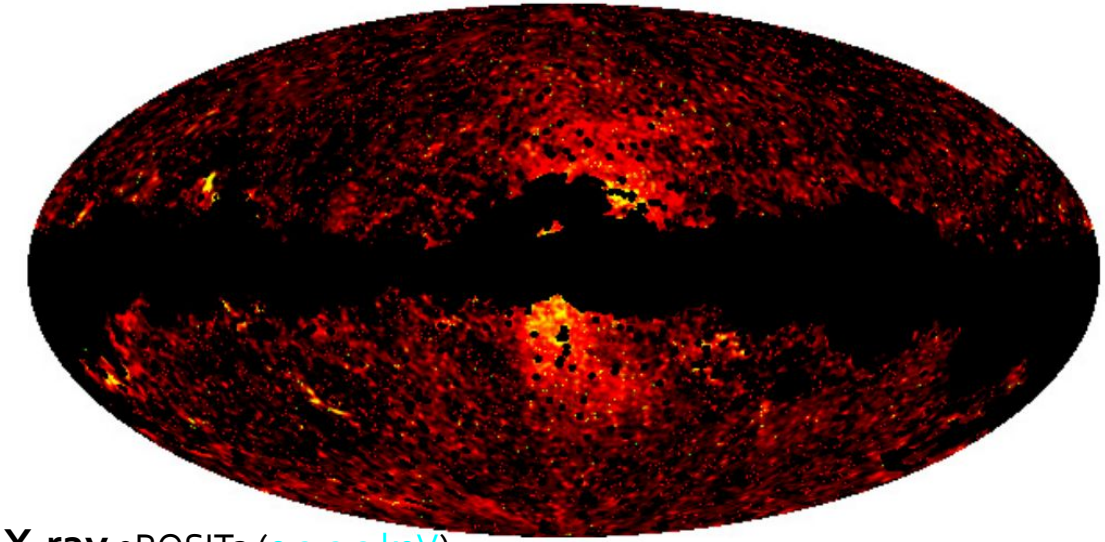
- WMAP (Finkbeiner 2004)
- Planck (PIR IX 2013)

Only in intensity.

Interpretation: synchrotron radiation, activity of Galactic Center. Still unclear.

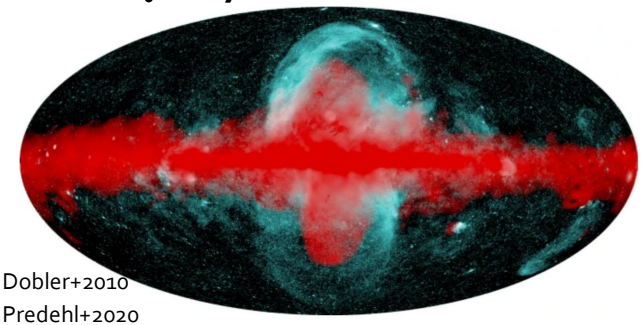
Possibly related counterparts:

Microwaves (I) Planck (30 and 44 GHz, PIR IX)



X-ray eROSITa (0.3-2.3 keV)

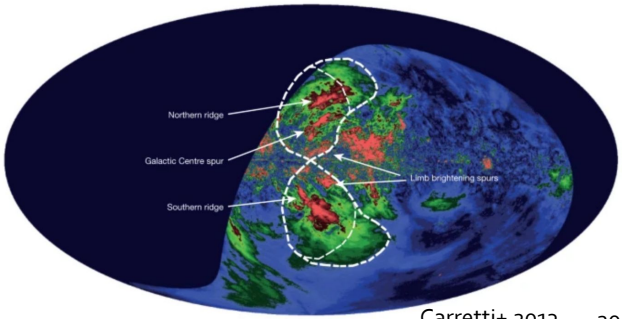
γ-ray Fermi (2-50 GeV)



Dobler+2010

Predehl+2020

Radio (P) S-PASS (2.3 GHz)



Carretti+ 2013

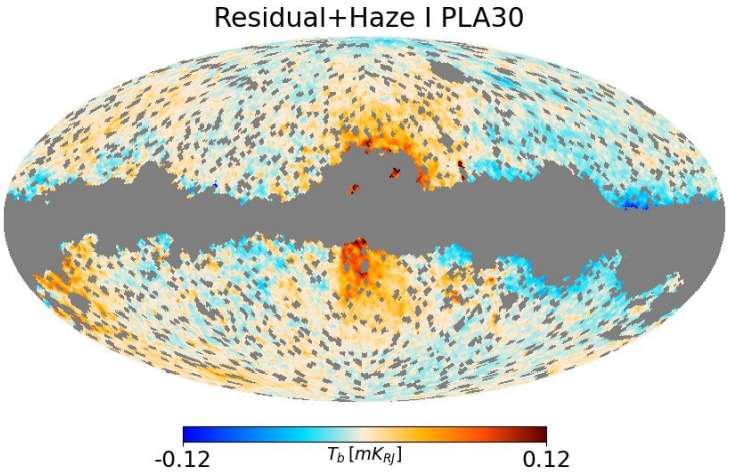
The Haze

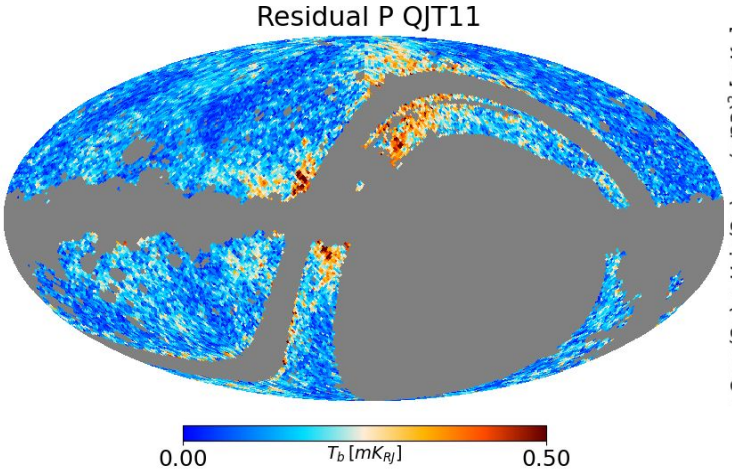
Including new QUIJOTE data:

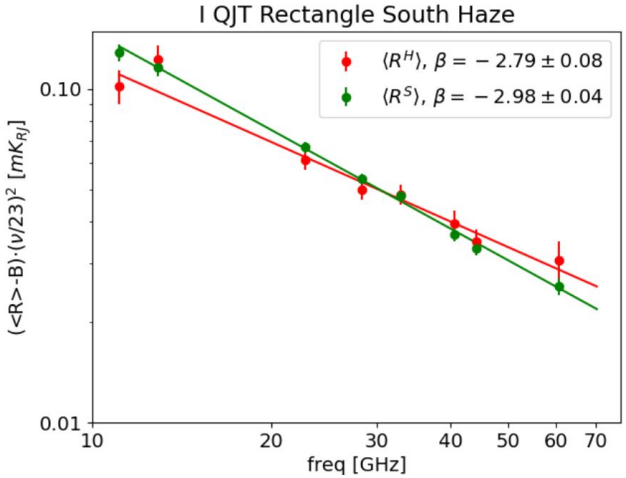
- We reproduced previous works in intensity obtaining a slightly steeper Haze spectral index (e.g., β = -2.5 in PIR IX 2013)

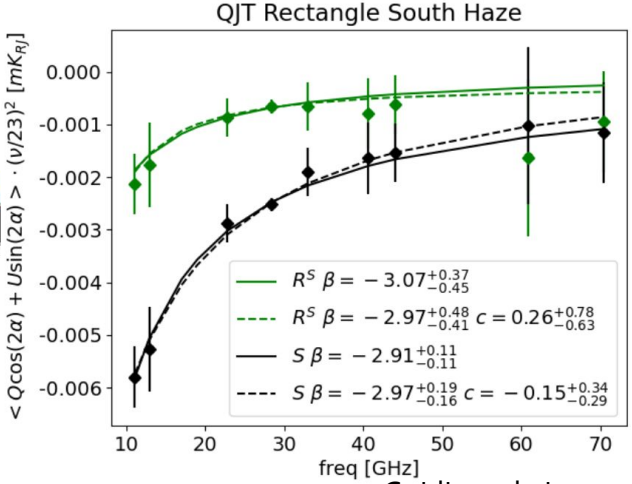
Same analysis in polarization:

- provided an hint detection of polarized Haze and/or of curvature of the spectrum









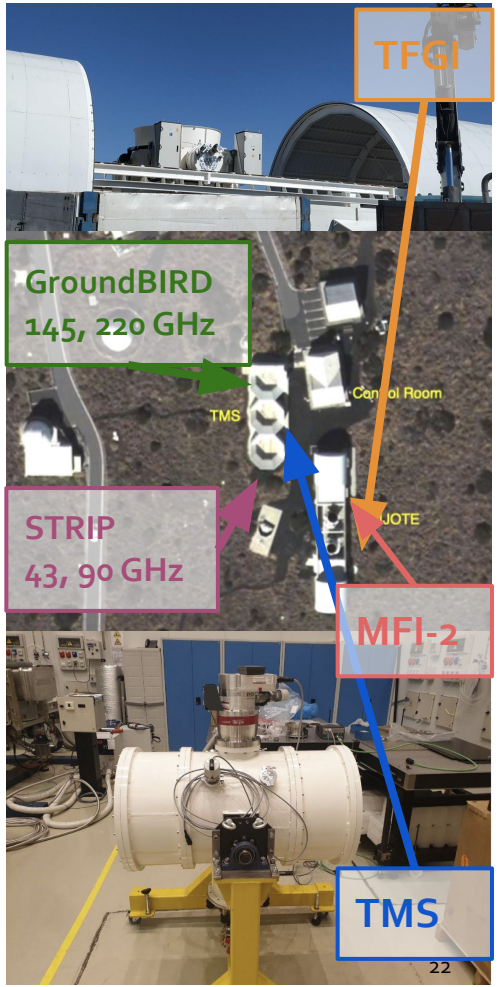
Guidi et al., in prep

Future of CMB from Tenerife

1. **TGI** and **FGI**: 30 (14 pix) and 40 (15 pix) GHz instrument.
   a. Angular resolution: 0.32°-0.26°
   b. Target sensitivity: 100 μK ⋅ sqrt(s)
   c. New installation in Nov 2021 → routine observations
   d. Science goals: low frequency foregrounds + B-modes, r ~0.05 after 3 years

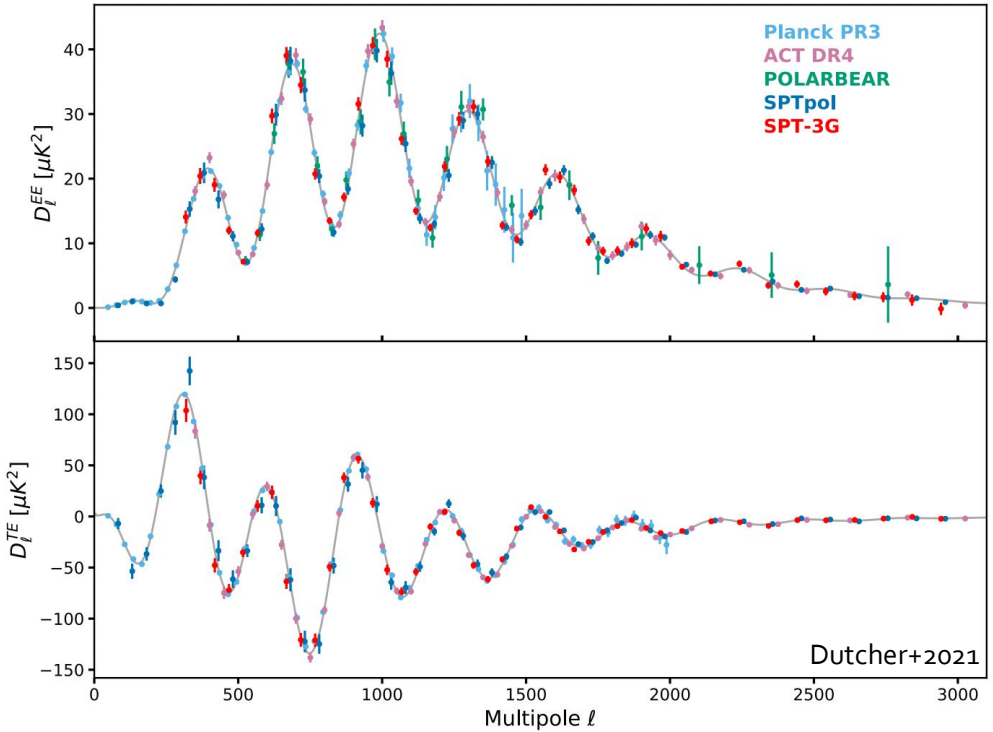
2. **MFI2**: new multi-frequency instrument
   a. Frequency coverage: three horns at 10–14 GHz, two horns at 16–20 GHz.
   b. Digital backend based on FPGA for RFI removal.
   c. Installation at QT1 end 2021.
   d. Science goals: same as MFI, increasing the mapping speed by a factor 3.

3. **TMS**: Tenerife Microwave Spectrometer (Rubiño Martín et al., 2020; Alonso-Arias et al., 2020).
   a. Installation: 2022
   b. Frequency coverage: 10-20 GHz → complementary to MFI2.
   c. Spectral resolution: 0.25 GHz (40 frequency bands)
   d. Angular resolution: ≈2°
   e. Science goals: characterization of the absolute synchrotron monopole from our Galaxy, and pathfinder for CMB spectral distortions.



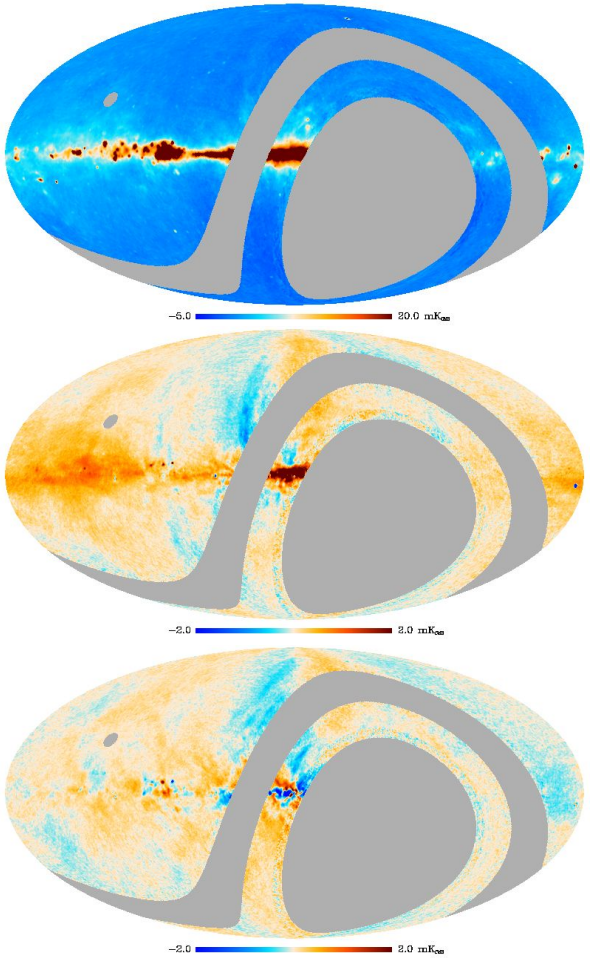
My present & future

NEUCosmoS: New era of EUropean CMB Cosmology with the South Pole Telescope (PI: Silvia Galli)



Conclusions

- New QUIJOTE maps are coming out soon (will be publicly available)
- New detailed characterization of polarized synchrotron
  - spatial variation of the spectral index
  - single power law in frequency
  - r = 0.01 at 90 GHz
- New hints for the understanding of AME
- Next future:
  - TFGI (30 and 40 GHz)
  - MFI-2 (new 10-20 GHz maps)
  - TMS (10-20 GHz spectrometer)



Thank you for listening!