CHARACTERIZING THE PROPERTIES OF THE ATMOSPHERIC EMISSION IN THE 10-20 GHZ RANGE WITH QUIJOTE DATA

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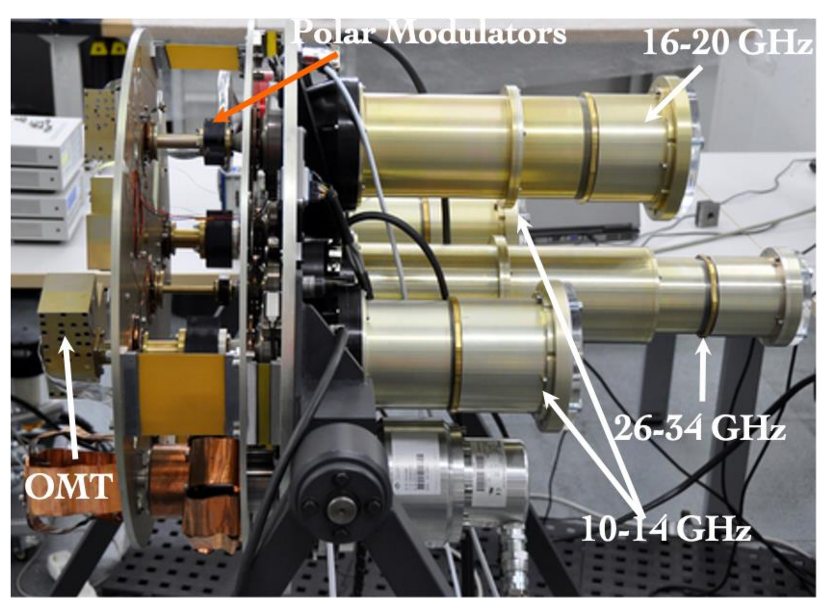
Abstract

The QUIJOTE MFI instrument (2012–2018) observed the sky in four frequency bands (11, 13, 17, and 19 GHz) with 1° angular resolution. For ground-based Cosmic Microwave Background experiments such as QUIJOTE, the atmosphere is the main source of contamination in intensity data. Using the full MFI dataset, we characterized the correlation properties of the atmospheric signal in these bands. Our analysis included the cross-correlation of time-ordered data (TOD) between the signals of QUIJOTE horns operating at the same frequency, as well as the cross-power spectrum of atmospheric signals. We find that the atmosphere remains stable over timescales of 1–2 hours and follows a Kolmogorov spectrum, with some indications of the detection of the outer scale. These results will contribute to improve current sky models at these frequencies and can be applied to future analyses of MFI data or to the preparation of new observations (e.g., with the Tenerife Microwave Spectrometer). Finally, we use dedicated MFI "skydip" observations to estimate the atmospheric water vapor content, comparing our results with GNSS (Global Navigation Satellite systems) measurements.

The QUIJOTE Experiment

- QUIJOTE (Q-U-I JOInt TEnerife): CMB Experiment, collaboration between Spain and the UK. It consists of 2 telescopes measuring the polarization of the sky at 10-40 GHz and at angular scales of 1°. It is located at the Teide Observatory in Tenerife, a site with excellent atmospheric conditions for CMB research (dry and extremely stable atmosphere) [1].

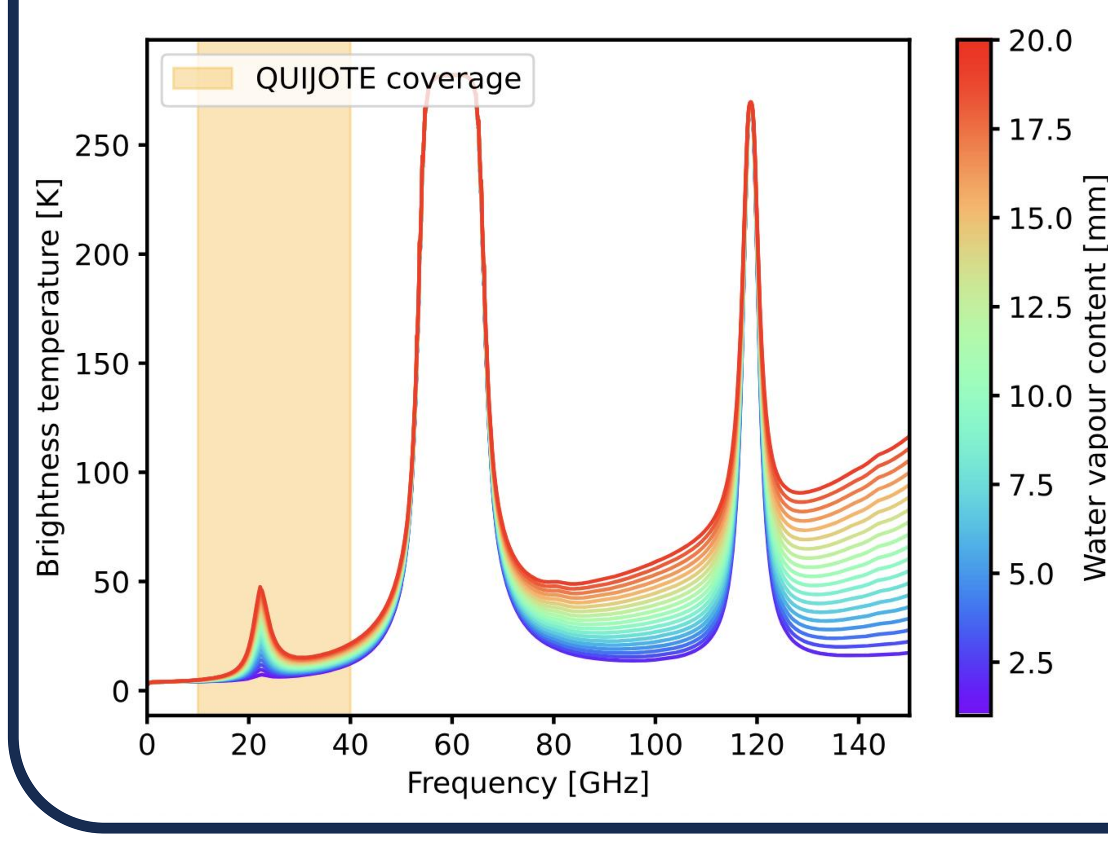
- The MFI (Multi-Frequency Instrument) was mounted on the QTI between 2012 and 2018 and is composed of 4 horns: 2 measuring at 11 and 13 GHz and other 2 at 17 and 19 GHz [1]. MFI2 is the upgrade of MFI and started operating in 2024.

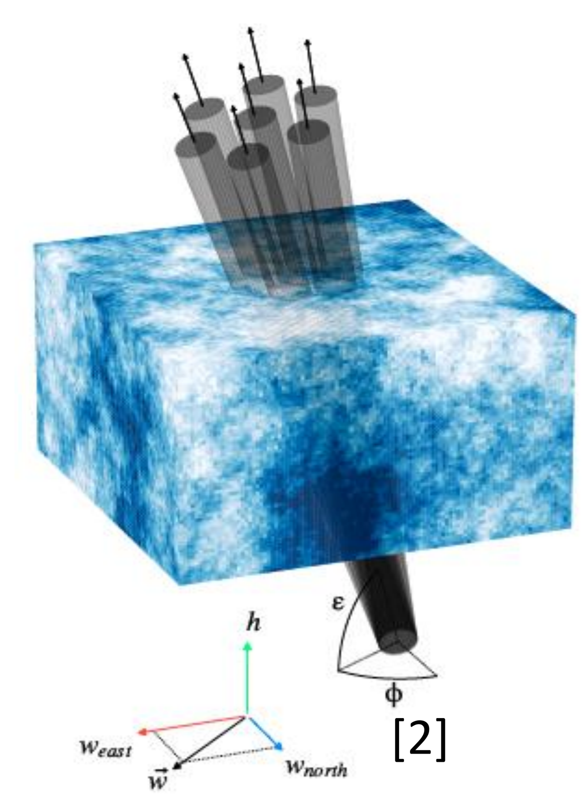


The atmospheric signals

- The atmosphere is the main source of contamination for ground based CMB experiments. Emission in the microwaves is produced mainly by two emission lines of water vapour at 22 GHz and 183 GHz, and two lines of molecular oxygen at 60 GHz and 120 GHz.

- Water vapour is the most problematic source of contamination, as it has a highly variable and inhomogeneous concentration in time and space.

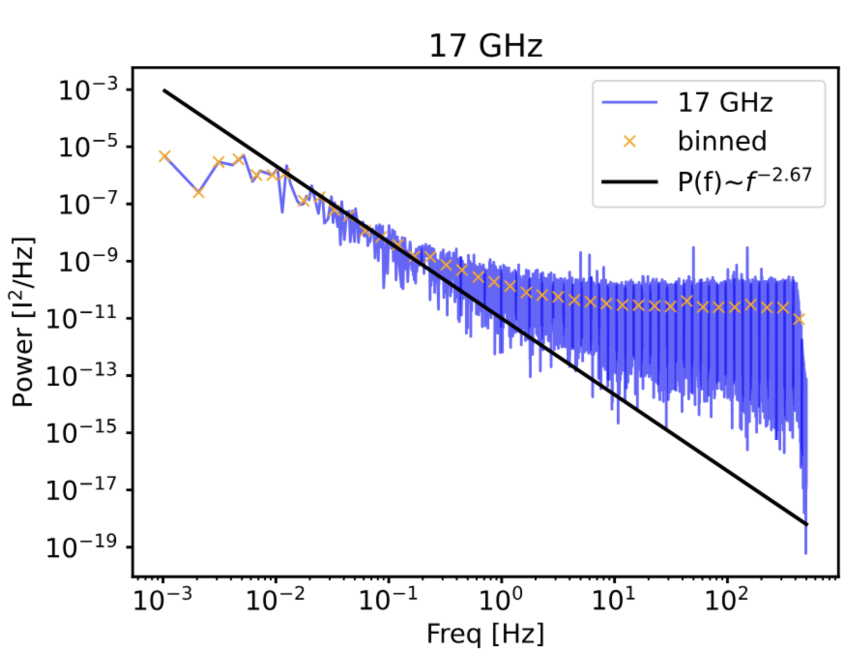




[2]

Characterization of the atmospheric emission in the 10-20 GHz with MFI and MFI2 data

→ Paper on arxiv



Power spectral density of the atmospheric signal:

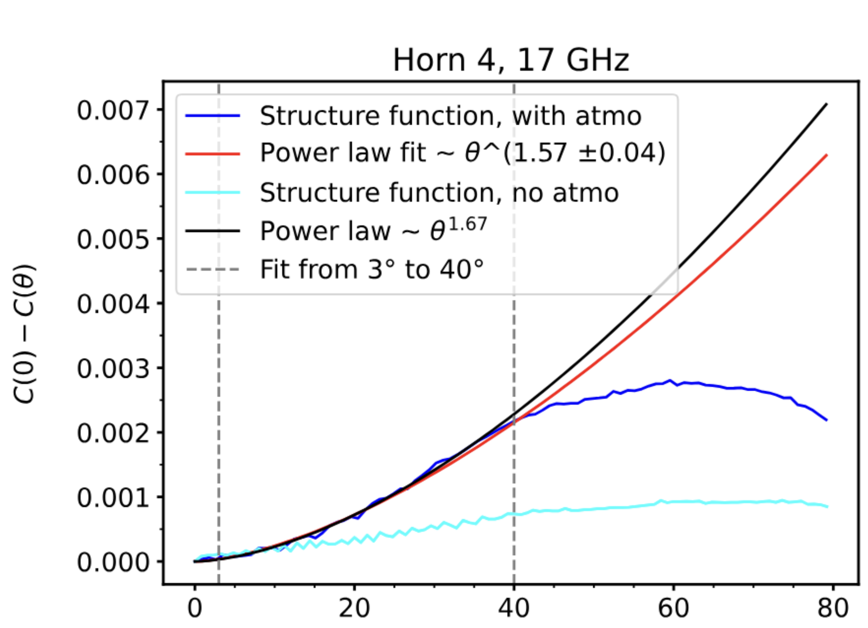
- Follows Kolmogorov Spectrum (black line).
- Evidence of the turbulence outer scales (flattening at low frequency).

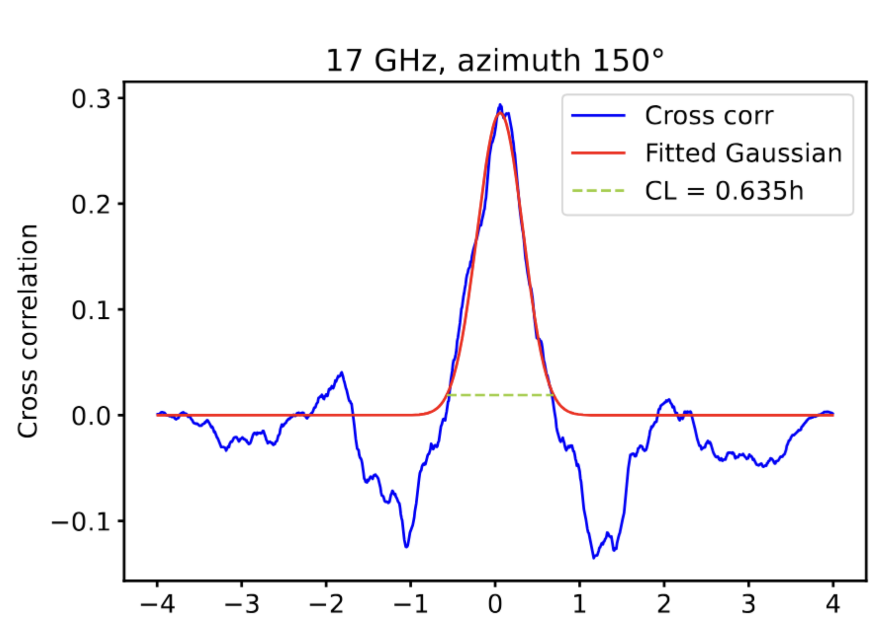
Angular structure function of the atmospheric signal:

- Follows Kolmogorov spectrum (black line) up to 40° angular separation.

Cross correlation function of the atmospheric signal:

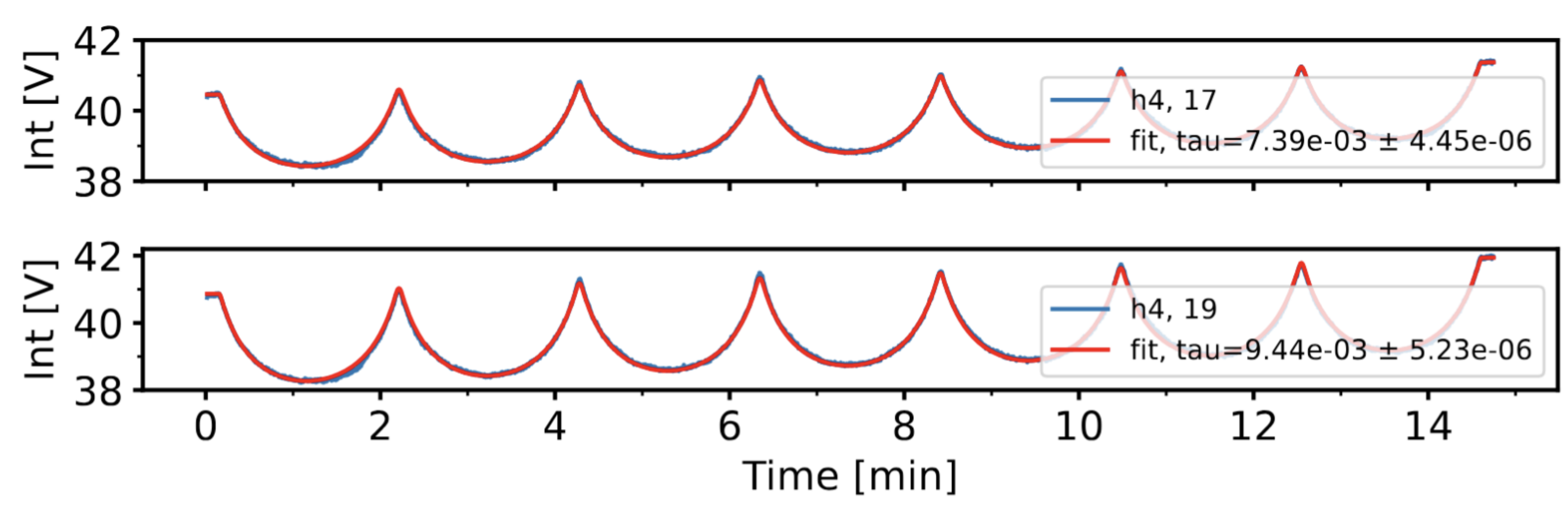
- We found that the atmospheric signal stays stable in a range of 1-2 hours [3].



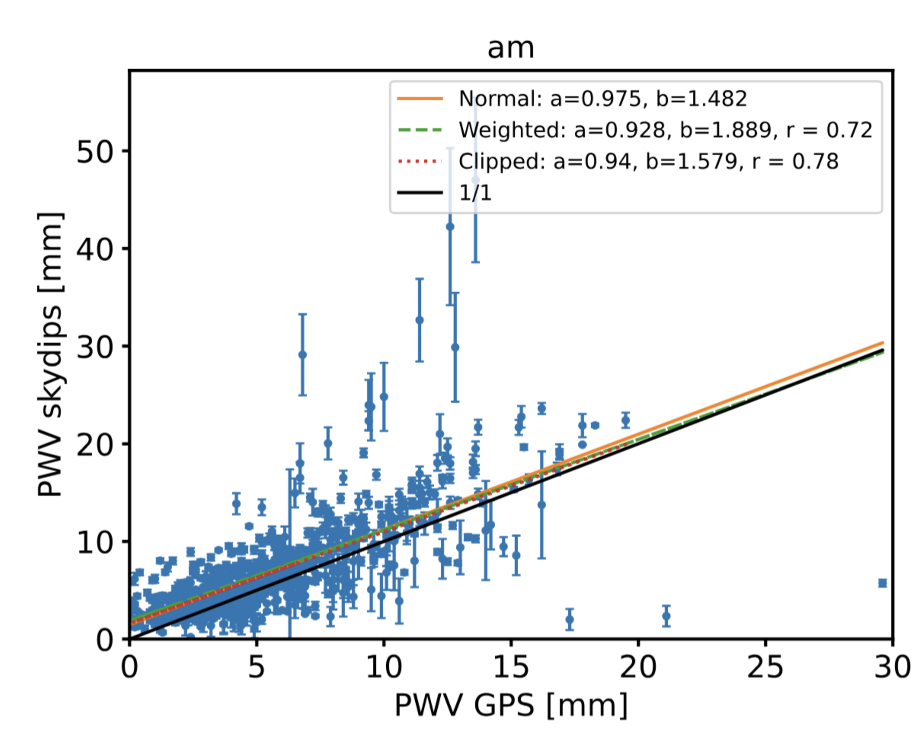


Opacity measurement and PWV determination with MFI

Skydip of MFI (elevation scans from 30° to 90°), fitted to retrieve the atmospheric opacity:



- From the opacity, retrieve the Precipitable Water Vapour (PWV) thanks to the *am* [4] and *ATM* [5] atmospheric models.
- Compare PWV obtained with MFI with on site PWV GNSS measurements [6].
- This allows to asses the reability of the atmospheric models [7].



Conclusion

In two papers [3,6], we characterized the atmospheric emission and asses the reliability of the *am* and *ATM* atmospheric models.

1. Rubiño Martín et al. (2023), MNRAS 519, 3383.
2. Morris et al. (2022), *Physical Review D*, *105*(4), 042004.
3. Chappard et al. (2025), *arXiv preprint arXiv:2510.19878*.
4. Paine, Scott. (2022). The am atmospheric model (12.2). Zenodo
5. Pardo et al. (2002), *266*, 188.
6. UREF GNSS station (IZAN), https://izana.aemet.es/?lang=en.
7. Chappard et al. (in prep).