

QUIJOTE and satellite interference



Mike Peel, 10 May 2022 (Photo: QUIJOTE CMB experiment)
on behalf of QUIJOTE collaboration

QUIJOTE summary

- Two 2.25m cross-Dragone telescopes (1.8m secondary)
- Located at 2400m altitude on Tenerife (PWV < 3.5mm for 50% of the time)
- Series of instruments:
 - MFI1: 10-14 + 16-20GHz survey, 2012-2018, results to come soon
 - TFGI: 30, 40GHz, ~30 pixels, survey starting soon
 - MFI2: 10-20GHz, higher sensitivity, digital back-end
- Part of a complex of radio telescopes
 - Previously Tenerife Experiment, COSMOSOMAS, Very Small Array (30GHz)
 - Now QUIJOTE + GroundBIRD (150+220GHz)
 - Soon + Tenerife Microwave Spectrometer (10-20GHz) + LSPE-STRIP (40+90GHz)
- No specific radio quiet zone! But aircraft exclusion, far from population centres.



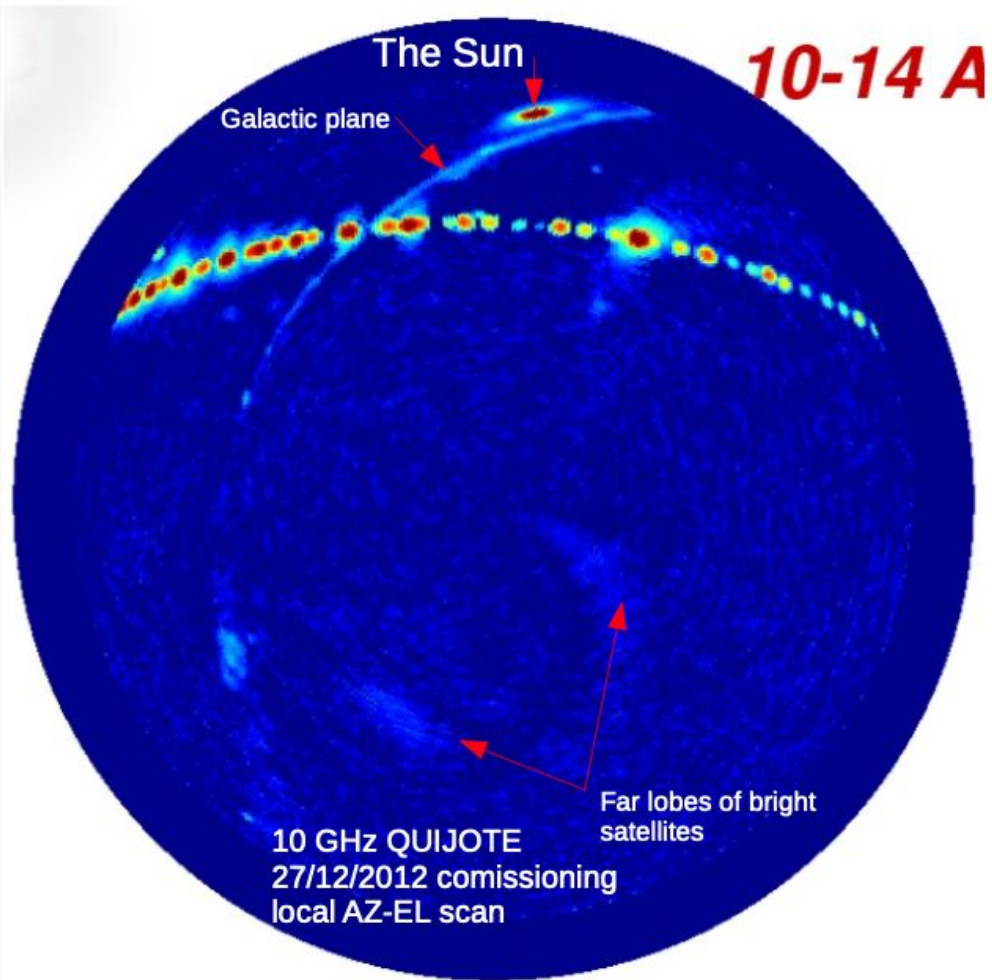
Comparison to satellite swarm frequencies

Constellation	Use	Start (GHz)	Stop (GHz)	Instruments affected
Starlink Ku-Ka	User downlink	10,7	12,75	MFI, TMS
	Gateway downlink	17,8	18,6	MFI, TMS
	Gateway downlink	18,8	19,3	MFI, TMS
	Gateway downlink	19,7	20,2	MFI, TMS
Starlink V band	Gateway downlink?	37,5	37,75	FGI
	User downlink?	37,5	42,5	FGI, LSPE-STRIP
OneWeb Ku-Ka	User downlink	10,7	12,7	MFI, TMS
	Gateway downlink	17,8	18,6	MFI, TMS
	Gateway downlink	18,8	19,3	MFI, TMS
Kuiper Ka	User/GW downlink	17,7	18,6	MFI, TMS
	User/GW downlink	18,8	19,3	MFI, TMS
	User/GW downlink	19,3	19,4	MFI, TMS
	User/GW downlink	19,7	20,2	MFI, TMS

<http://research.iac.es/proyecto/cmb/pages/posts/impact-of-satellite-ldquomega-constellationsrdquo-on-cmb-experiments-at-the-teide-observatory2.php>

MFI in 2012

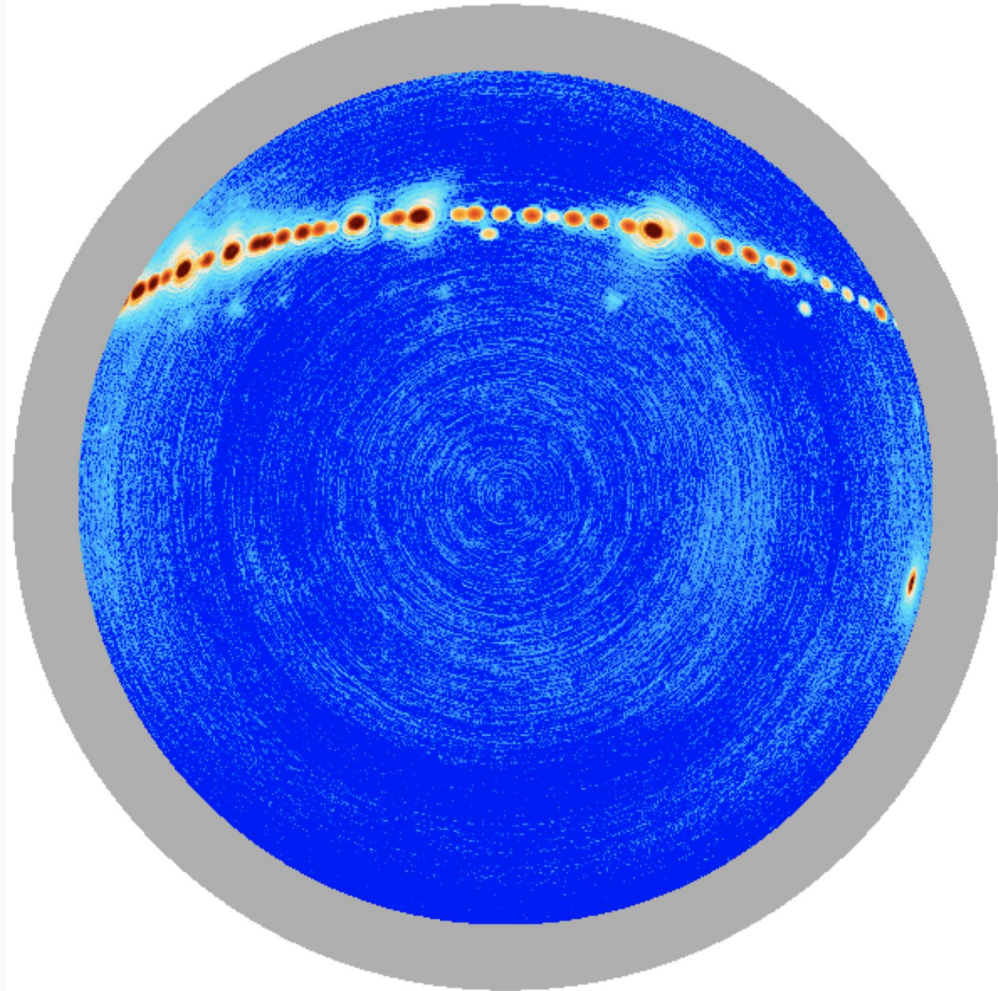
- 10–20 GHz local map (scan in azimuth, step in elevation)
- The Sun, our Galaxy, ...
- Geostationary satellites!
 - **Brighter than the sun!**
- Satellite signals reflected from the edges of the dish
 - Strong sidelobes far away from geostationary band



MFI in 2014

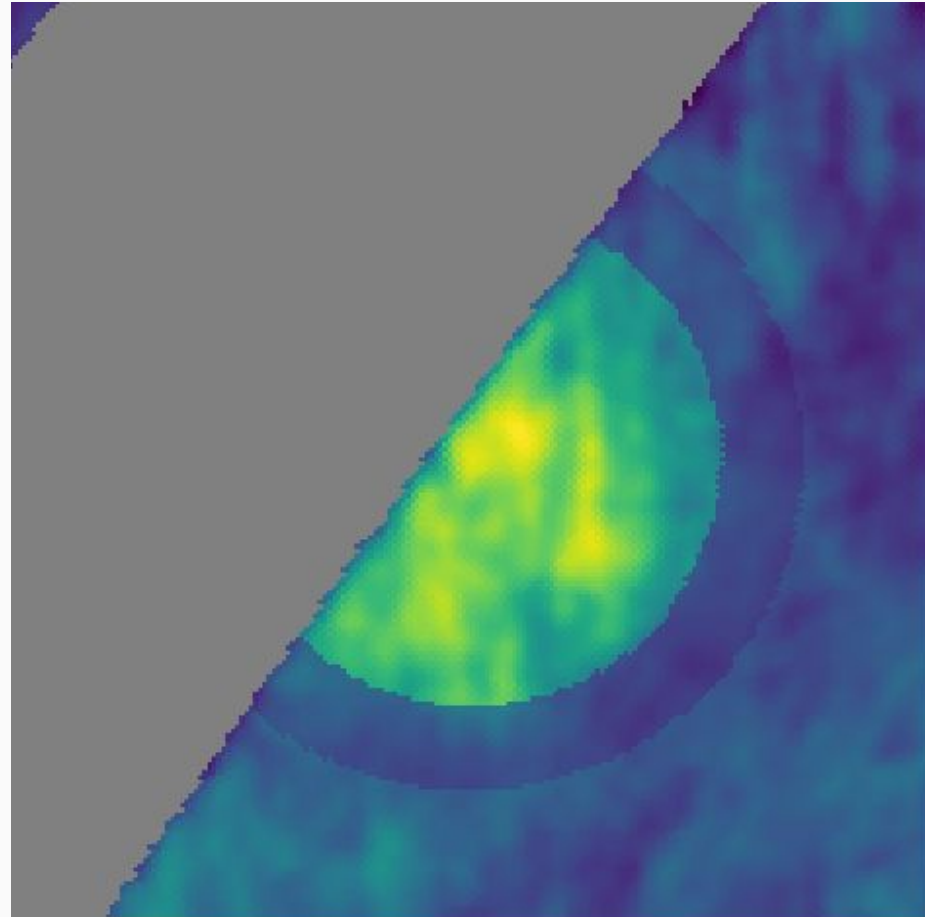
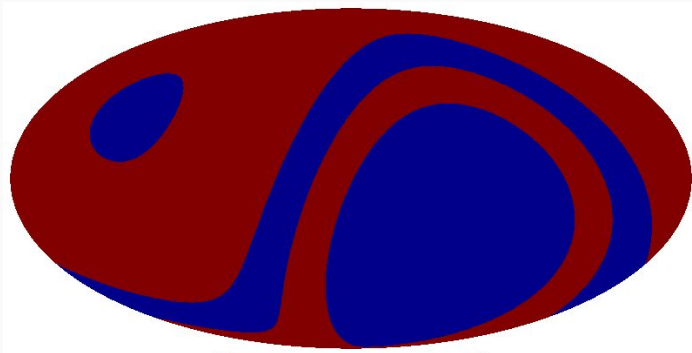
- After installing baffle on QT1
- Far-out sidelobes reduced
- Can't do anything about geostationary band
 - Just mask that declination range out completely!!!
 - (Note the sidelobes close to satellites still - really bright!)

Baffle



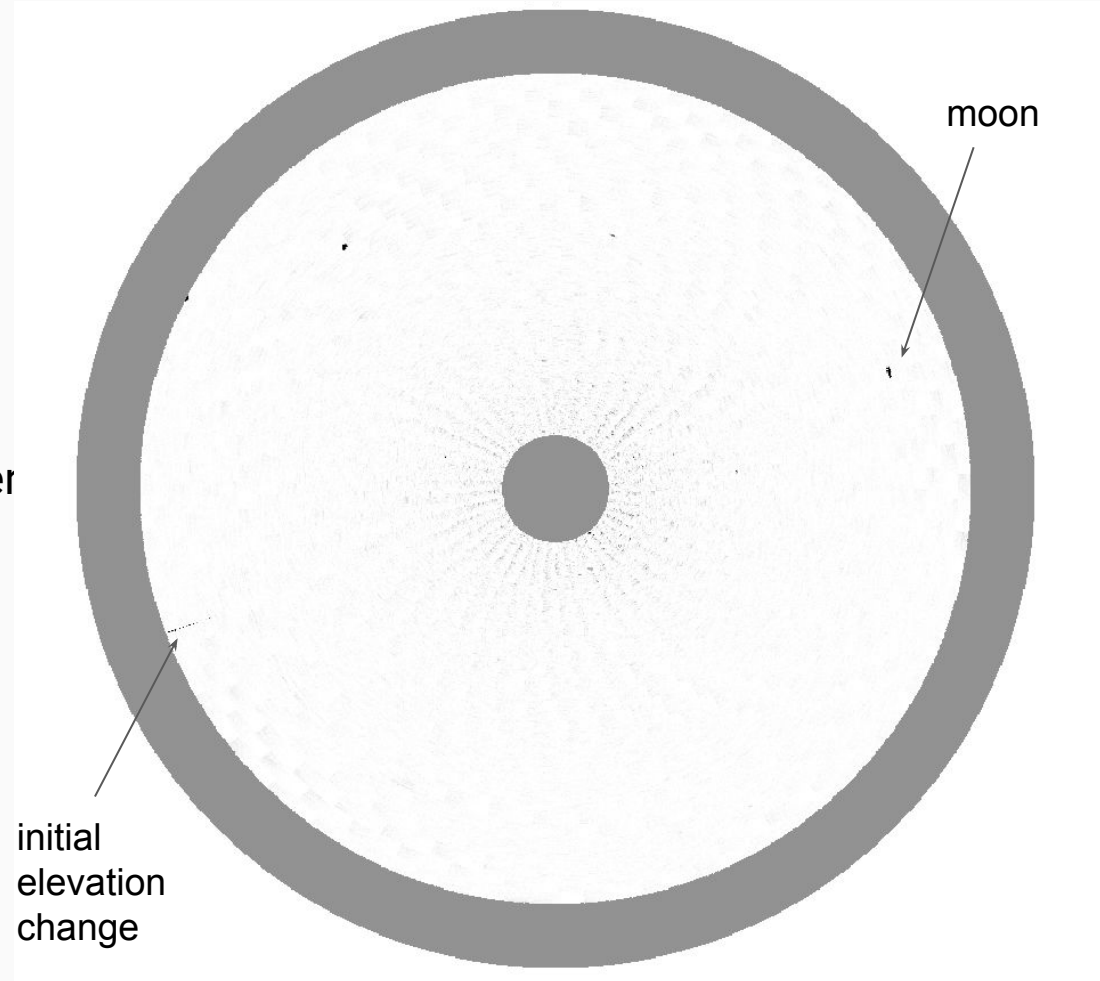
Real on-sky impact?

- Zeta Ophiuchus
- One of my favourite sources
- Really complex to understand
- Seems to have more high-freq signal than expected (but not spinning dust?)
- Multi-freq component separation would be nice
- But we only see half the source with QUIJOTE—thanks GEO sats!
- (Maybe could be filled in with a southern telescope—but \$\$\$!)



TFGI in 2021

- 30 GHz local map (scan in azimuth, step in elevation)
- Moon on the right
- Some geostationary satellites
 - Not as bad as expected!
 - Expect an increasing number in the future...
- (Ignore spiral pattern, due to median subtraction of $1/f$)



What do signals look like? (small dish)

Presumed
Starlink satellites

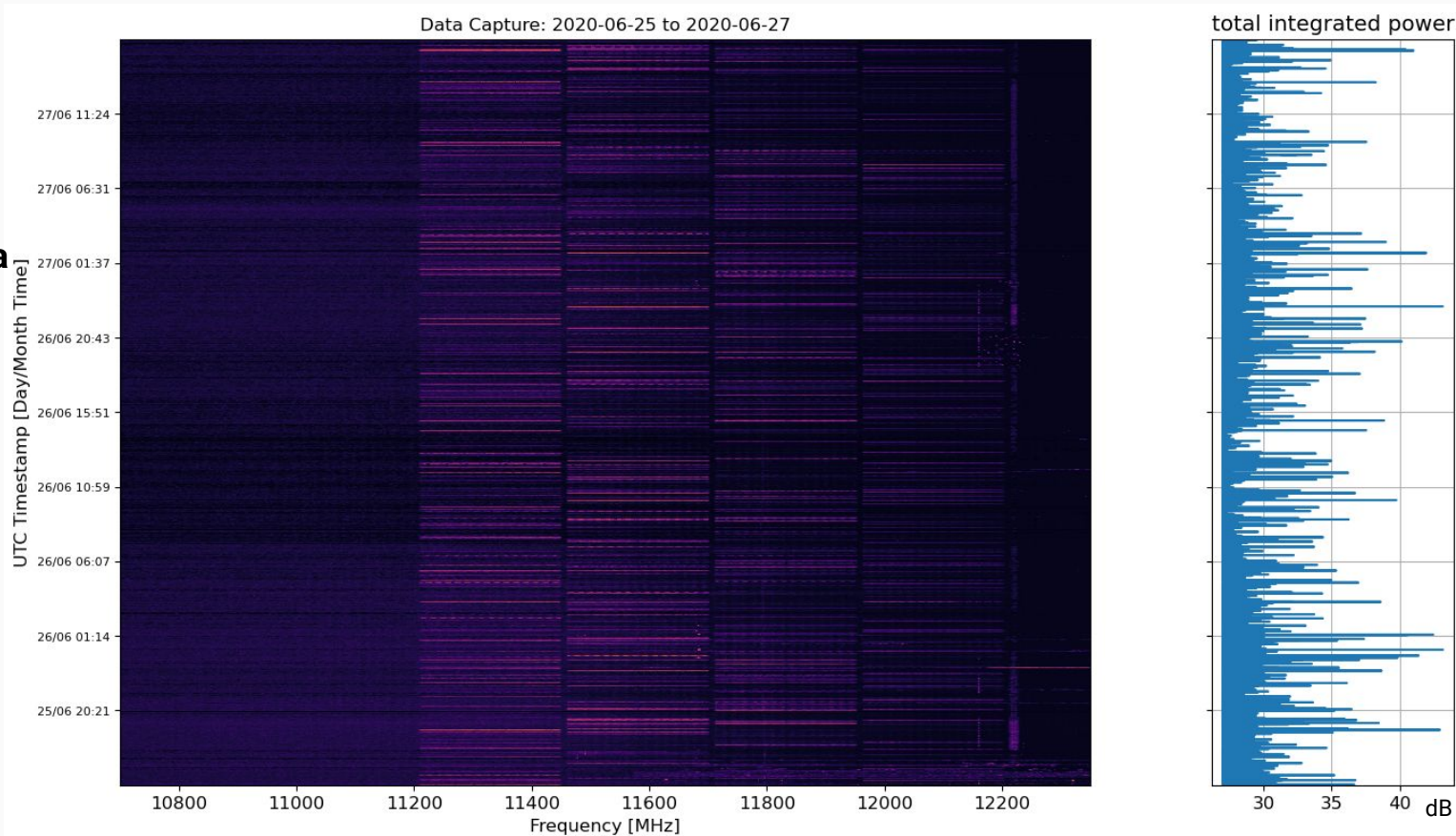
Single pointing
direction

11.2-12.2GHz **data**
badly
contaminated
(1GHz band!)

Variable
(due to satellite
movement)

This is over 1.5
days

Thanks to
Federico Di Vruno
(SKAO)



Next steps

- MFI1 stopped observing in 2018, MFI2 under construction, nearly ready
- When MFI2 starts running (2022/23), will probably see a lot more satellites!
- Currently trying a small 60cm satellite dish to start seeing signals in Tenerife
- TFGI currently observing at 30+40GHz, can see some geostationary satellites, but not many yet... Trying to monitor regularly.
 - (Starlink V-band approved but not operational yet?)
- Really need more data on this! If anyone has access to a telescope at these frequencies, please have a look!
- Happy to chat offline about any of this: mpeel@iac.es