

QUIJOTE extensions

The Ninety GHz Instrument and the ELFS-SA receiver

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On behalf of the QUIJOTE NGI and ELFS-SA collaborations

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The QUIJOTE experiment

(Q-U-I JOint Tenerife Experiment, <http://research.iac.es/project/quijote>)

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

QT-1. Instruments: MFI, MFI2.
11, 13, 17, 19 GHz. Bands=2GHz.
FWHM=0.93°-0.62°

MFI: 2012-18.

MFI2: 2023

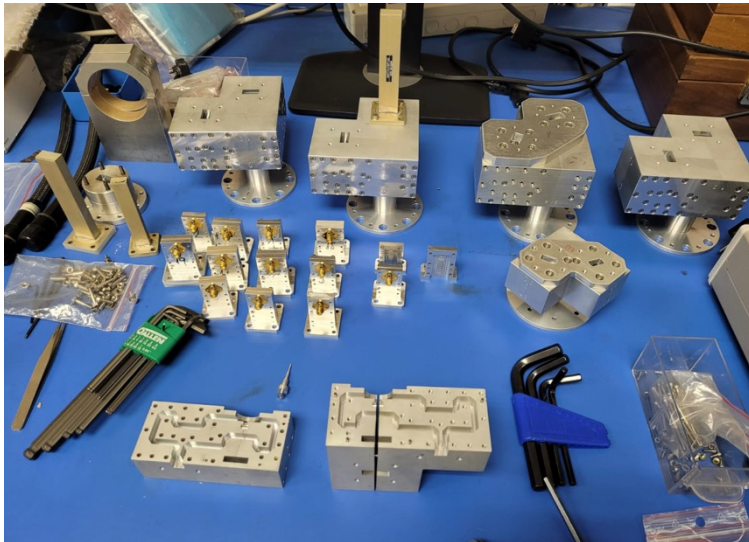
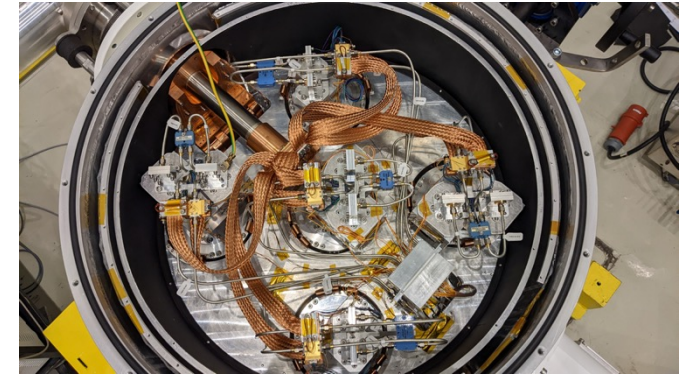
QT-2. Instruments: TGI & FGI
30 and 40 GHz. Bands=10GHz
FWHM=0.37°-0.28°
Commissioning 2018.
Observations re-started 2021.

90GHz camera.
2000 detectors (KIDs).



MFI2 Instrument (10-20 GHz)

- ❖ **MFI upgrade (MFI2 @ QT-1).** Aim: to increase the integration speed of the MFI by a factor 3.
- ❖ **5 horns.** Three covering the 10-14GHz band, and two covering 16-20GHz.
- ❖ **Full digital back-end (FPGAs)** → RFI removal (TV sats, Megaconstellations Starlink, OneWeb, Kuiper).
- ❖ **Status:** Installed at QT1. Commissioning with old MFI DAS started March 2024. New DAS (FPGA based) for late 2024.
- ❖ **Operations:** 3 effective years.



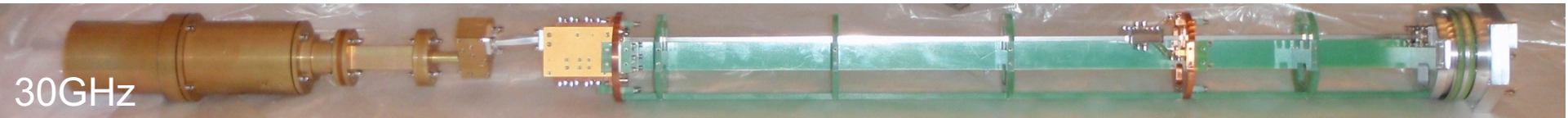
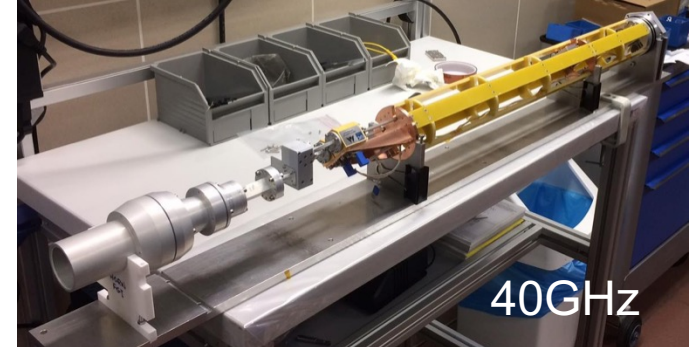
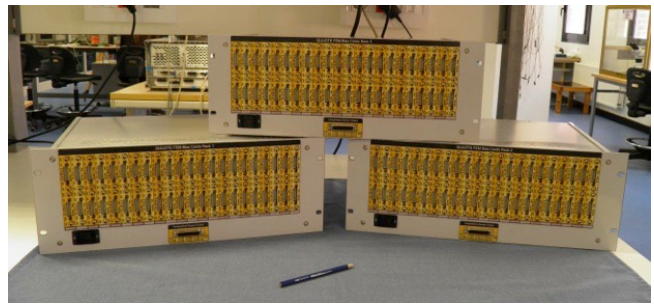
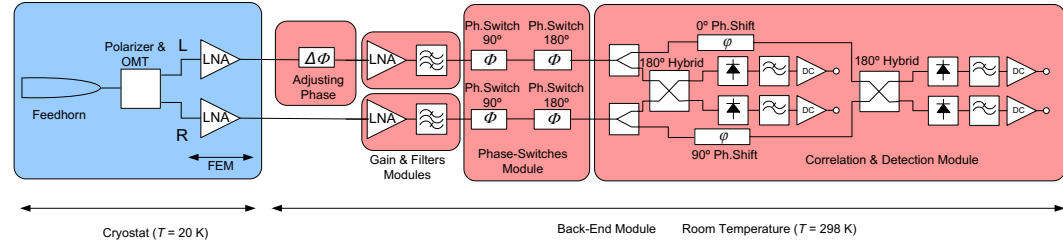
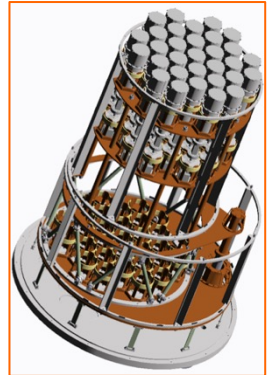
(Hoyland et al. 2022, SPIE)





Quijote **TGI (30 GHz) and FGI (40GHz)** instruments @ QT2

- ❖ **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 (TFGI) observations started in 2018.** Stopped during 2020. Problem with the cryostat fixed → Nov2021-Oct2022 with 7 pixels. Now installing 19 detectors.

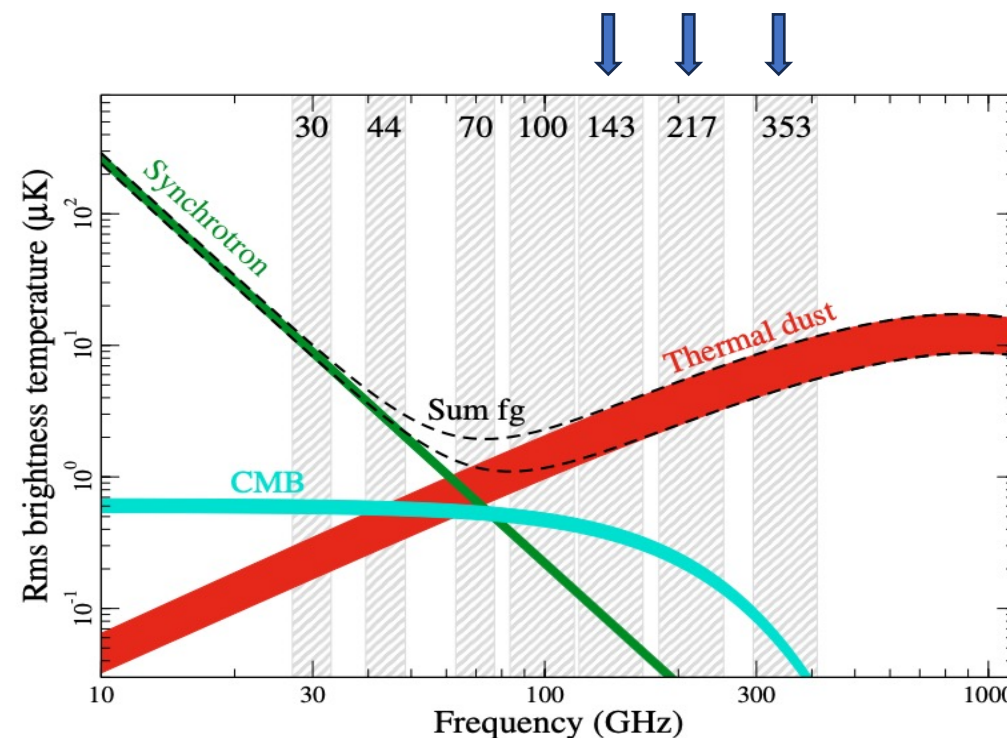
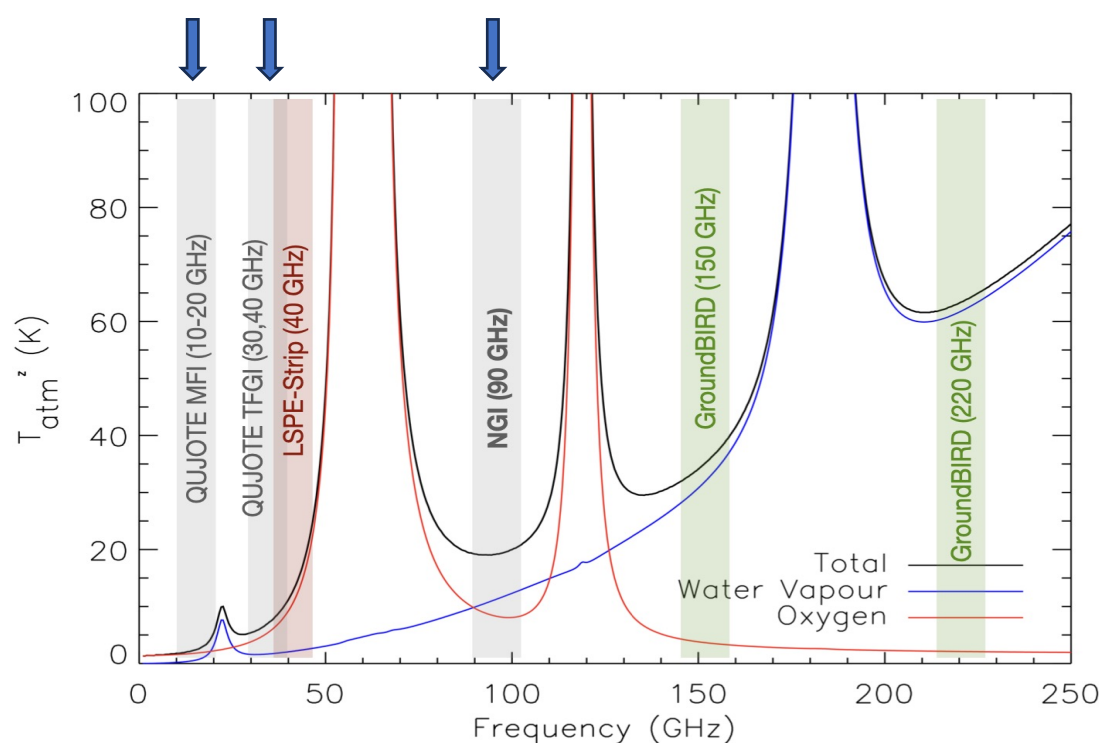


The Ninety GHz Instrument for the QUIJOTE telescope T2



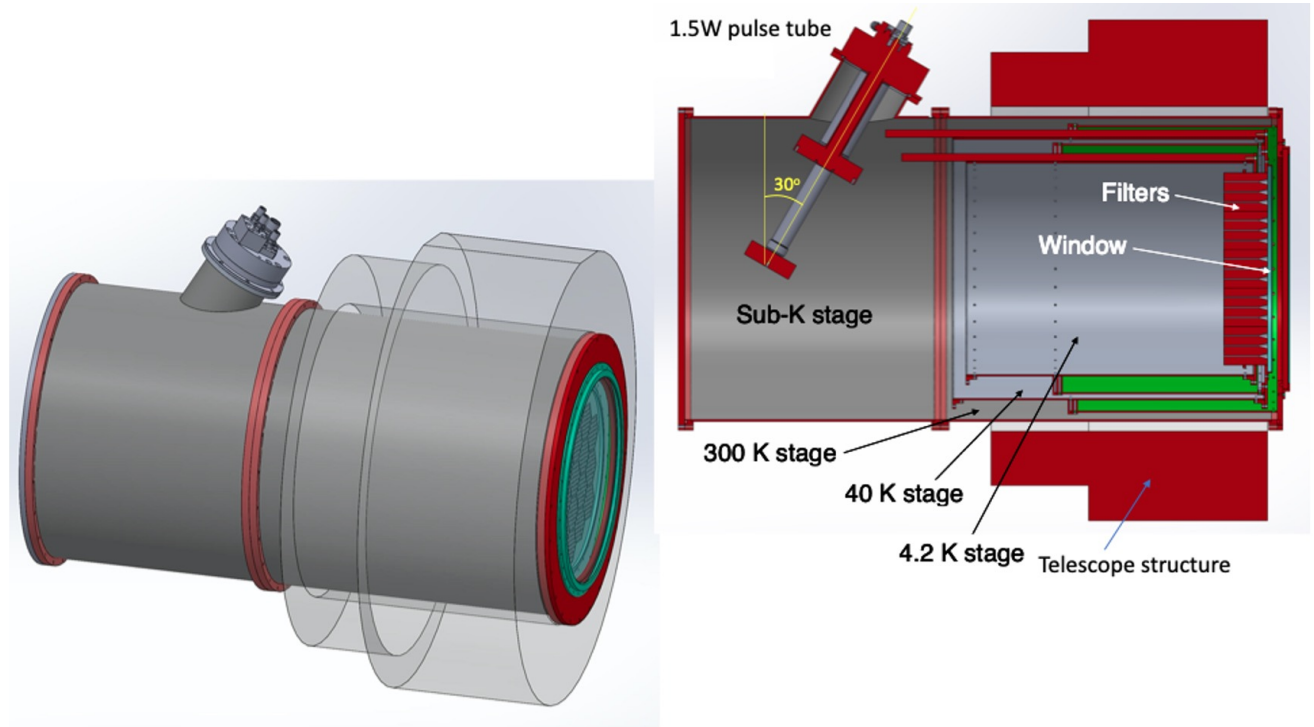
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- A new QUIJOTE instrument in the W-band atmospheric window will extend the current 10-50 GHz frequency coverage of the MFI2, TGI and FGI instruments to the cosmological 90 GHz band.
- The main scientific goal of NGI is the detection or constraint of the primordial B-mode. Besides, NGI will allow additional scientific objectives such as the study of the properties of the Galactic emission and its relation with the structure of the Galactic magnetic field and the characterization of the Sunyaev-Zeldovich effect in clusters of galaxies.



Main components of the NGI

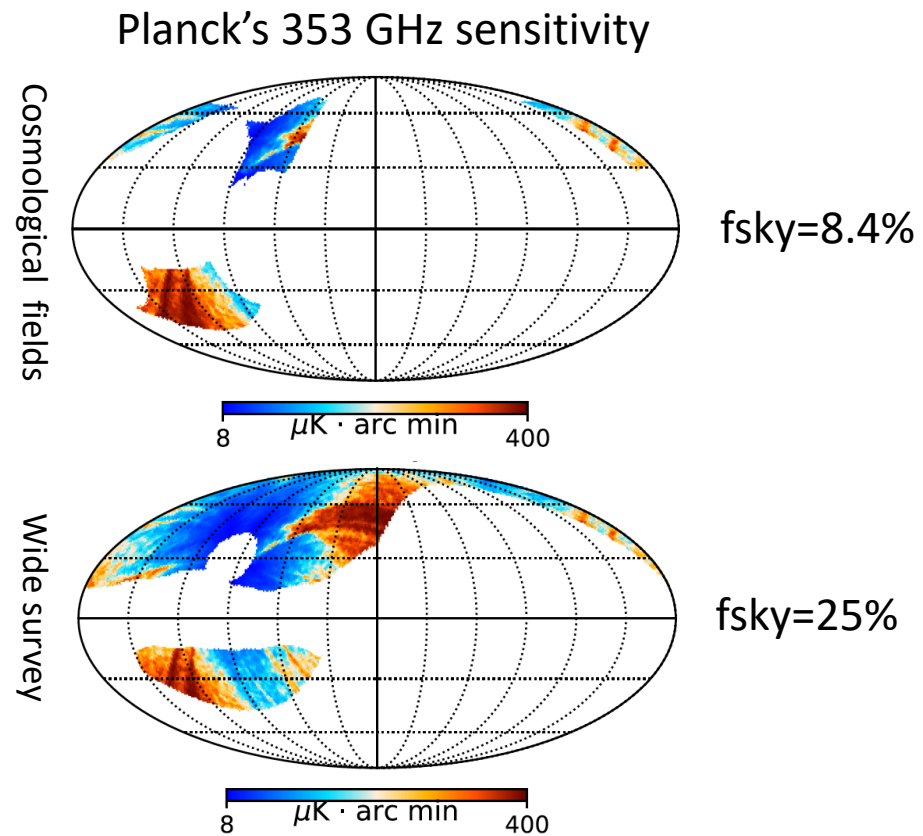
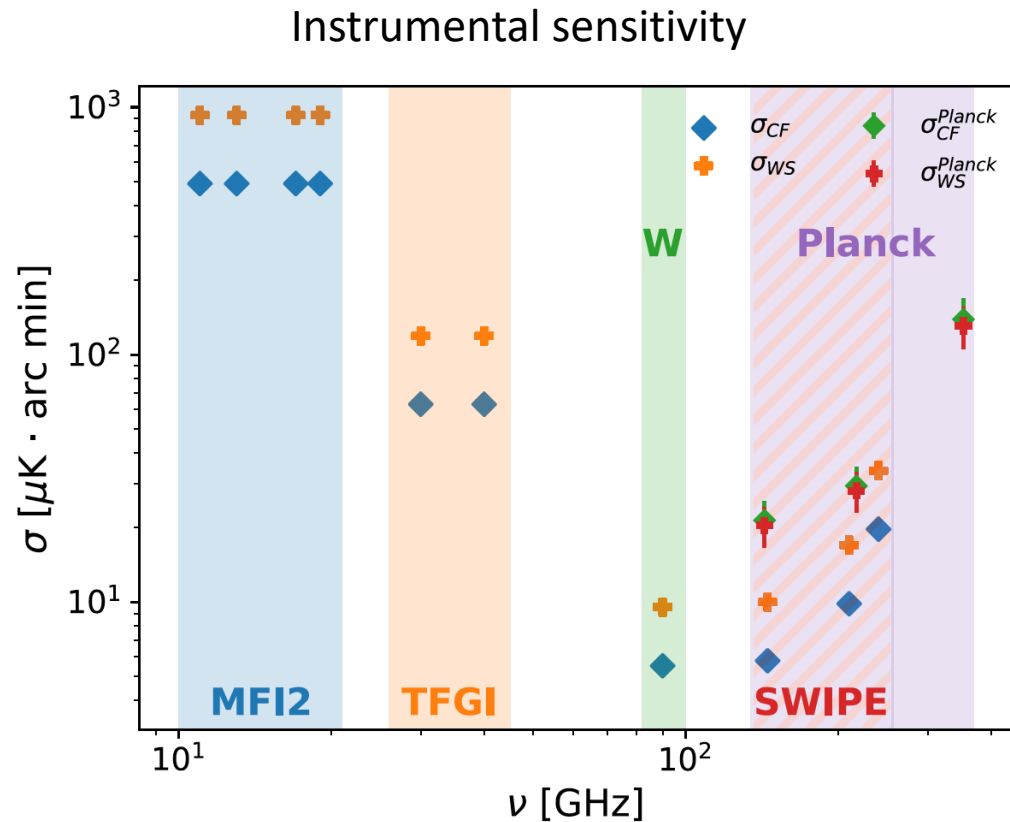
- **Cryostat:** composed of several cryogenic stages, a pulse tube refrigerator of the first stages of 40K, 4.2K, and an absorption refrigerator to reach the final temperature of 150mK.
- **Detectors:** ~2000 Kinetic Inductance Detectors (KIDs) cooled at 150mK.
- **Horns and waveguides:** ~1000 elements.
- **Polarization modulation unit:** a Half Wave Plate and a rotating mechanism to rotate at a constant speed and at room temperature. The rotating mechanism is based on a magnetic levitation system.
- **Optical system:** ARC polypropylen window at the entrance of the cryostat at room temperature, together with two thermal filter layers. Additional filters are included in the lower temperature stages at 40K, 4.2K and 150mK. Optical resolution ≈ 7 arcmin.
- **Read-out electronics and data acquisition:** formed by a chain of LNAs, coaxial cables and a read-out electronic system based on FPGAs.



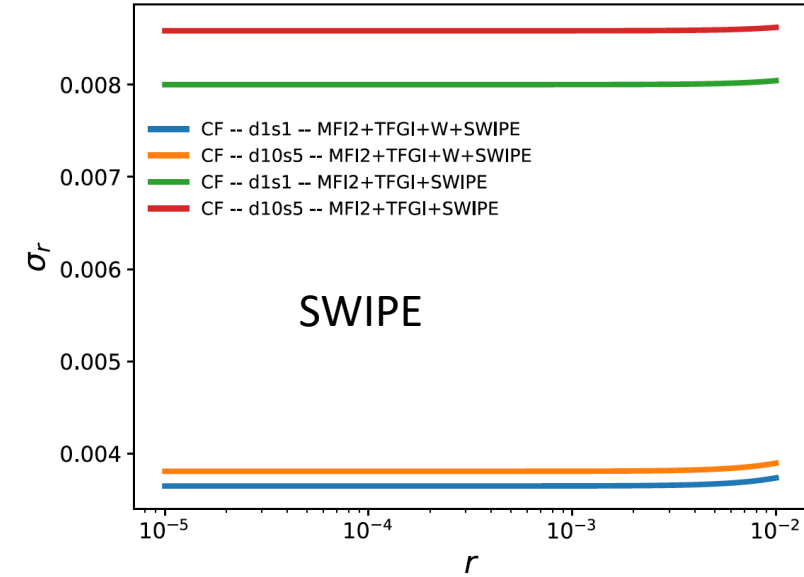
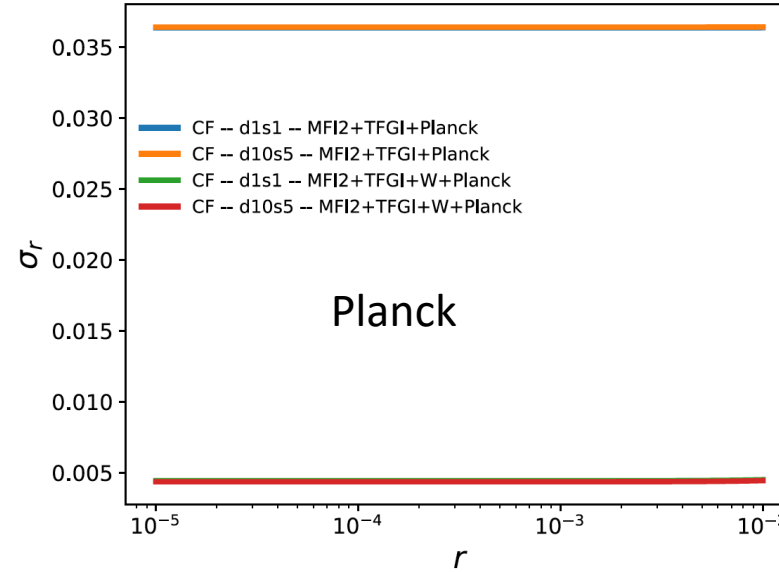
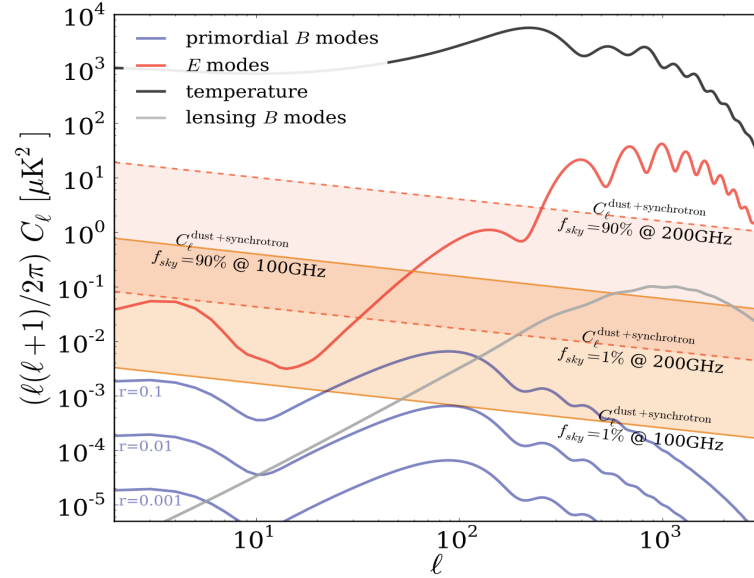
Schematic representation of the cryostat

r sensitivity using Northern Hemisphere data from QUIJOTE+NGI+Planck

Observational strategy: cosmological fields or wide survey



Forecast on r sensitivity



- Including the W-band improves significantly the sensitivity on r :
- Including the W-band with 7.2 effective months of data (2 years of observations), $\sigma_r \lesssim 0.005$ either with Planck or SWIPE

$\sigma^{\text{no W-band}}/\sigma^{\text{W-band}}$	Planck	SWIPE
CF	8.2	2.2
WS	4.1	2.6

The European Low Frequency Survey on the Simons Array



SISSA



- The European Low frequency survey (ELFS) is a long term plan to produce a 5-100 GHz full-sky survey with ~ 20 arcmin angular resolution at 10 GHz, sub-GHz spectral resolution and sensitivity that will allow next generation experiments a robust B-mode extraction.

- ELFS-SA is a first step in which a X-band (6-12 GHz) receiver is deployed in one of the Simons Array telescopes providing ~ 20 arcmin. It will be followed by the installation of the QUIJOTE-MFI2 instrument (10-20 GHz) once the Northern Hemisphere survey is finished.

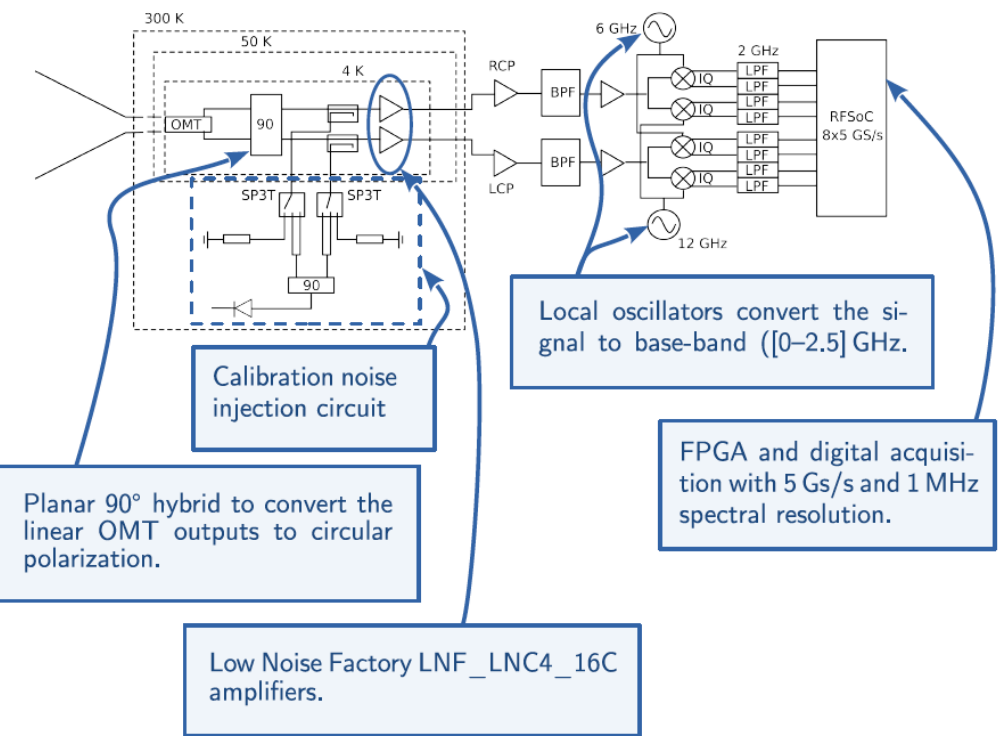


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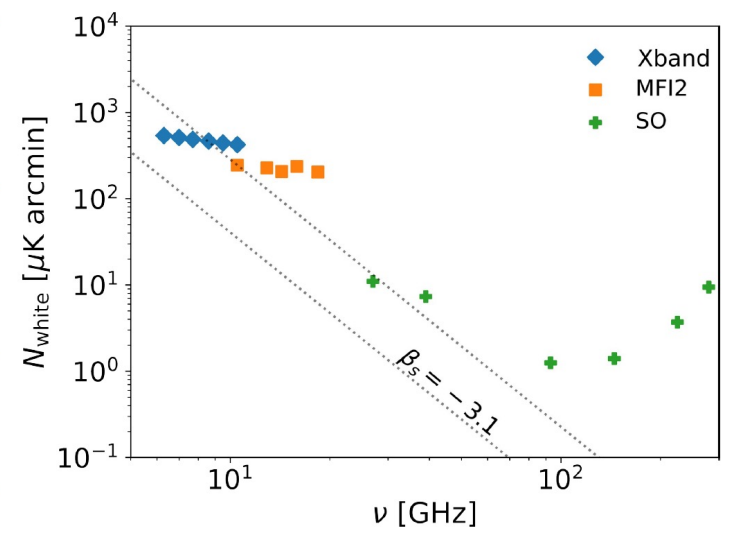
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The X-band receiver

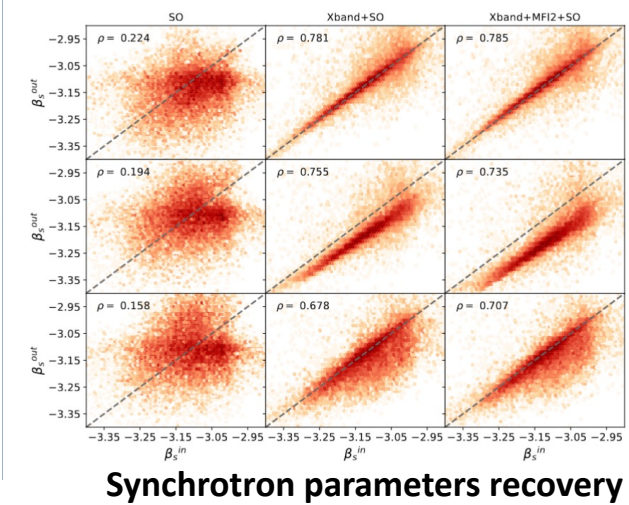
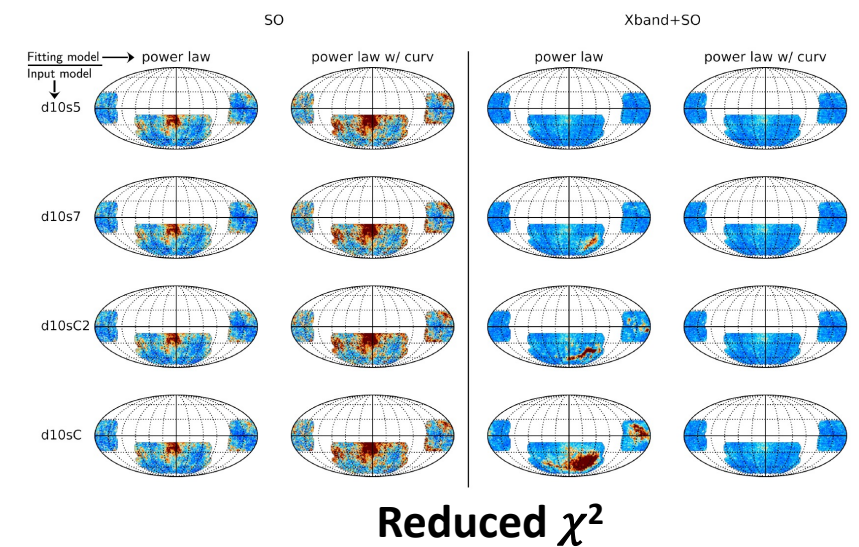
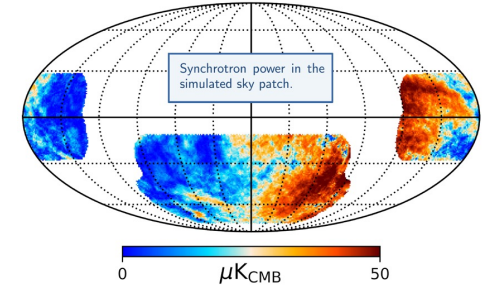


Instrumental sensitivities

Experiment	ν	FWHM	N_{white}	ℓ_{knee}	α_{knee}
Nominal	27	91	33	15	-2.4
	39	63	22	15	-2.4
	93	30	2.5	25	-2.5
	145	17	2.8	25	-3
Xband	225	11	5.5	35	-3
	280	9	14	40	-3
	6.3	46.6	539	15	-2.4
	7	42.2	512	15	-2.4
MFI2	7.7	38.1	487	15	-2.4
	8.6	34.4	465	15	-2.4
	9.5	31.1	443	15	-2.4
	10.5	28.1	423	15	-2.4
	10.5	33.7	245	15	-2.4
	12.9	27.4	228	15	-2.4
SO-SAT	14.3	24.8	206	15	-2.4
	15.9	22.2	236	15	-2.4
	18.4	19.2	203	15	-2.4



Simulated sky: CMB+Synchrotron+thermal dust



Synchrotron with a power law model fitted with a power law.

Synchrotron with a power law plus curvature model fitted with a power law.

Synchrotron with a power law plus curvature model fitted with a power law plus curvature.

Summary

- The QUIJOTE MFI2 (10-20 GHz) and TFGI (25-47 GHz) are already in operation and will measure the sky during the next 2-3 years.
- The new NGI will be a major extension of the current QUIJOTE experiment, opening a new window to observe the Northern Hemisphere at 90 GHz.
- The NGI is expected to start observations in 2027 and, combined with QUIJOTE data at other frequencies and Planck at the higher polarized channels, is expected to reach sensitivities $\sigma_r \lesssim 0.005$ in 2 years of observations (30% effective time) at the end of the decade.
- ELFS-SA will develop a X-band (6-12 GHz) receiver that will be installed in one of the Simons Array telescopes, followed by the installation of the QUIJOTE-MFI2 instrument.
- The X-band receiver will start operations next year and its data, and later the QUIJOTE-MFI2 instrument data, will allow next generation CMB experiments to significantly improve their control on Galactic foregrounds in the low frequency range.