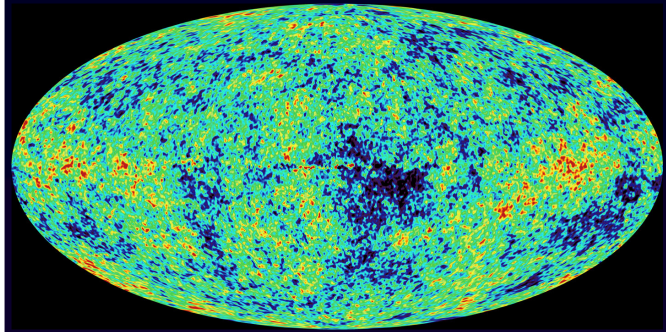

Polarization of the CMB:
"QUIJOTE" and the search for primordial gravitational waves

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and

Consejo Superior de Investigaciones Científicas

XVI Paris Observatory Cosmology Colloquium

Paris 25-27, July 2012

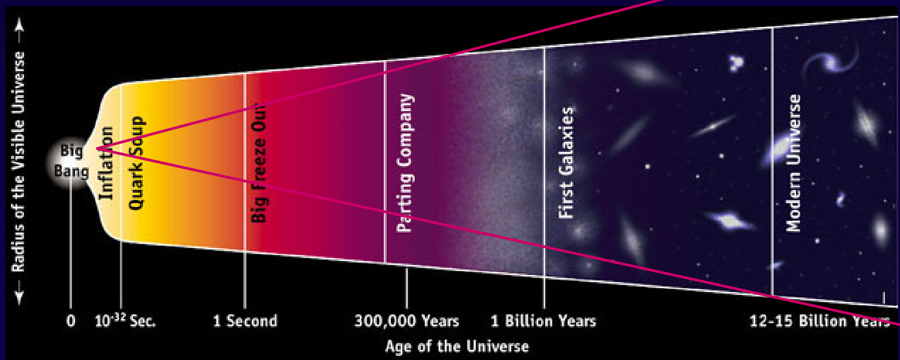
Outline

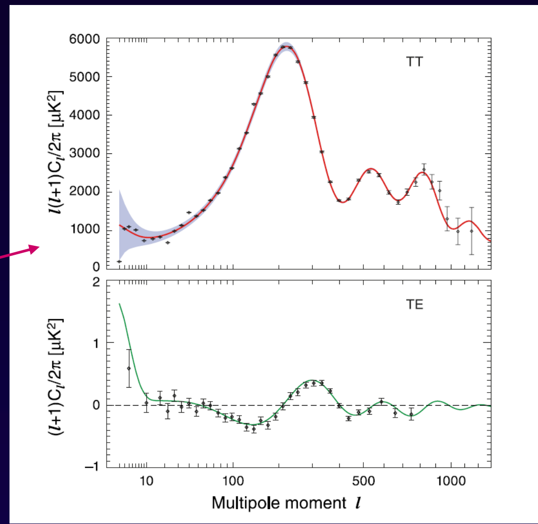
- Introduction
  - Inflation, Gravitational Waves and Polarization of the CMB
- CMB Polarization observations
- The QUIJOTE CMB experiment
  - Science: B-modes and Galactic foregrounds
  - Basic Features: Telescopes and instruments

A few notes on INFLATION

Guth 1981, Linde 1982, Albrecht Steinhardt 82, Sato 81, Muhanov..

Inflation, an early epoch of accelerated expansion with nearly constant energy density, reflects our present best understanding for the Physics of the very early Universe and the generation of the primordial cosmological perturbations. Physical processes underlying inflation reach the scale of Grand Unified Theories (GUTs) or 10^{15} GeV





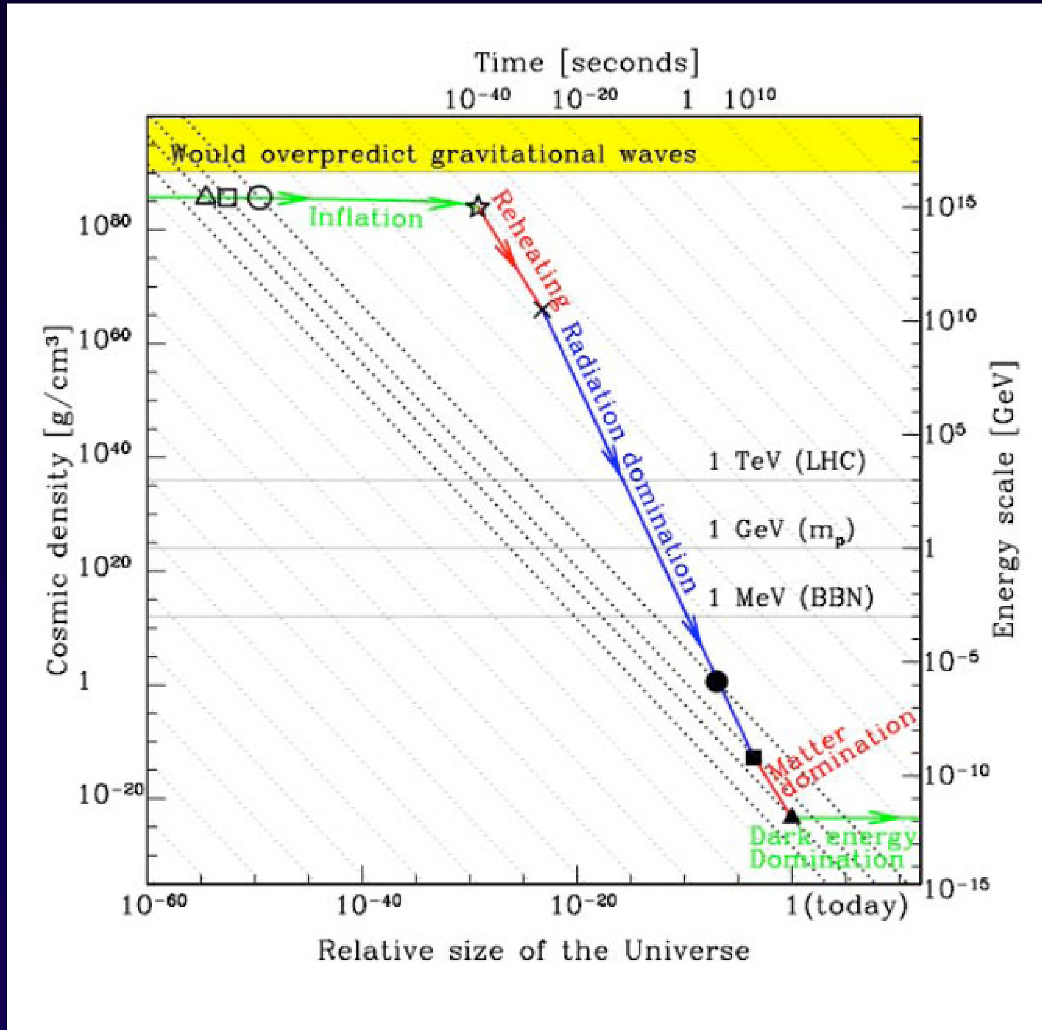
Inflation resolves the homogeneity, isotropy and flatness problems. Generates quantum fluctuations in matter fields and spacetime that lead to macroscopic fluctuations leaving an imprint on the CMB and on the large scale distribution of galaxies

Notes on Inflation (II)

$$a(t) \approx a(0)e^{Ht}, \qquad H \approx \text{const}.$$

Intense period of accelerated expansion of the Universe by >50 e-folds within less than 10^{-34} s. Causes dilution of any initial inhomogeneity and spatial curvature until they become negligible in the present universe.

Physical wavelengths grow faster than the horizon, fluctuations are stretched outside of the horizon and re-enter the Universe later.



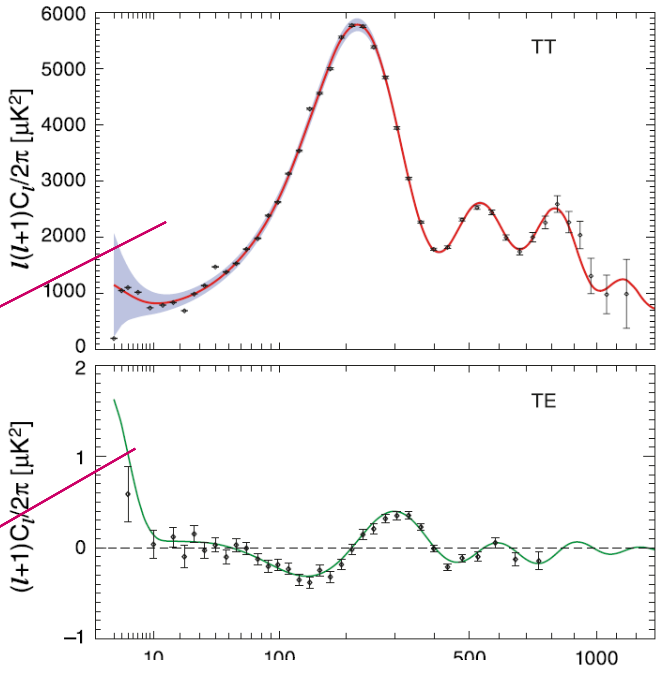
Scalar (density) fluctuations and primordial power spectrum

$$\alpha_s \equiv \frac{dn_s}{d\ln k}\,.$$

The power spectrum is often approximated by a power law form

$$P_s(k) = A_s(k_\star)\left(\frac{k}{k_\star}\right)^{n_s(k_\star)-1+\frac{1}{2}\alpha_s(k_\star)\ln(k/k_\star)}$$

where $k_\star$ is the pivot scale.



Inflation predicts primordial density fluctuations (nearly) scale-invariant, adiabatic and Gaussian

Label	Definition	Physical Origin	Current Status
A_s	Scalar Amplitude	V, V'	$(2.445 \pm 0.096) \times 10^{-9}$
n_s	Scalar Index	V', V''	0.960 ± 0.013
α_s	Scalar Running	V', V'', V'''	only upper limits

Tensor – gravitational wave - perturbations

$$n_t \equiv \frac{d \ln P_t}{d \ln k},$$

$$P_t(k) = A_t(k_\star) \left(\frac{k}{k_\star}\right)^{n_t(k_\star)}.$$

??

$$P_{tensor} = \frac{8}{m_{Pl}^2}\left(\frac{H}{2\pi}\right)^2 \propto E_{\inf}^4$$

The amplitude of this power spectrum is a model independent measurement of the Energy scale of Inflation

An example: Models of single field slow-roll inflation

$$P_s(k) = \frac{1}{24\pi^2 M_{\rm pl}^4} \frac{V}{\epsilon}\bigg|_{k=aH}, \qquad n_s - 1 = 2\eta - 6\epsilon\,,$$

$$P_t(k) = \frac{2}{3\pi^2} \frac{V}{M_{\rm pl}^4}\bigg|_{k=aH}, \qquad n_t = -2\epsilon\,, \qquad r = 16\epsilon\,.$$

where

$$\epsilon \equiv -\frac{\dot{H}}{H^2} = \frac{M_{\rm pl}^2}{2}\frac{\dot{\phi}^2}{H^2} \approx \frac{M_{\rm pl}^2}{2}\left(\frac{V'}{V}\right)^2, \qquad |\eta| \approx M_{\rm pl}^2\left|\frac{V''}{V}\right|.$$

The tensor to scalar ratio depends on the time evolution of the inflaton field

$$r \equiv \frac{P_t}{P_s}\,.$$

$$r = 16\epsilon = \frac{8}{M_{\rm pl}^2}\left(\frac{\dot{\phi}}{H}\right)^2$$

$$r = -8n_t$$

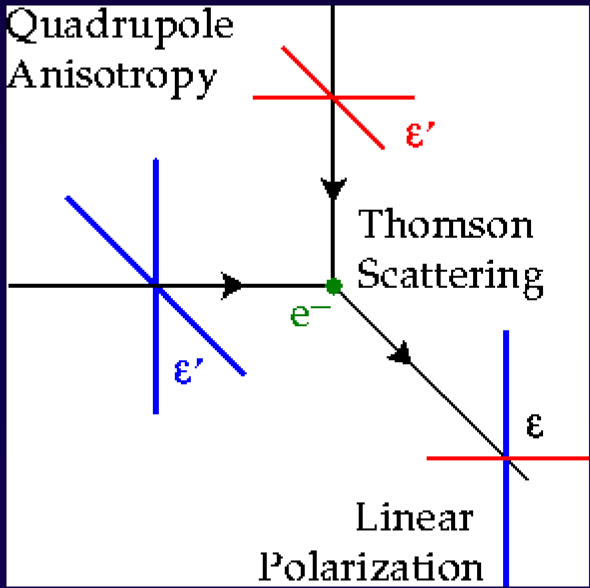
Imprint of the Primordial Gravitational Waves on the Polarization of the Cosmic Microwave Background

The polarization of the CMB

- **Differential cross section for Thomson scattering depends on polarization → scattering generates polarization**

- A net polarization is generated during recombination if there is a quadrupole anisotropy in the radiation field.
- For a multipole decomposition of the radiation field into spherical harmonics, the five quadrupole moments are represented by l=2, m=0,±1, ±2.

  Orthogonality of spherical harmonics → only the quadrupole moment can generate polarization from Thomson scattering.



- The net polarization generated via scattering is **linear** (i.e. the CMB will have non-zero Stokes parameters Q and U, but V=0).

Notation

Stokes parameters

$$I = |E_1|^2 + |E_2|^2 \qquad Q = |E_1|^2 - |E_2|^2$$

$$U = (E_1^* E_2 + E_2^* E_1) = 2\mathrm{Re}(E_1^* E_2) \qquad V = 2\,\mathrm{Im}(E_1^* E_2)$$

All-sky decomposition (spin-s spherical harmonics)

$$(Q \pm iU)(\hat{n}) = \sum_{\ell=2}^{\infty} \sum_{m=-\ell}^{+\ell} a_{\ell m}^{\pm 2}\ {}_{\pm 2}Y_{\ell m}(\hat{n}) = \sum_{\ell=2}^{\infty} \sum_{m=-\ell}^{+\ell} (a_{E,\ell m} \pm i a_{B,\ell m})\ {}_{\pm 2}Y_{\ell m}(\hat{n})$$

$$\int d\hat{\mathrm{n}}\, {}_sY_{\ell m}^*(\hat{\mathrm{n}})\, {}_sY_{\ell m}(\hat{\mathrm{n}}) = \delta_{\ell\ell'}\delta_{mm'}$$

$${}_sY_{\ell m} \rightarrow e^{\pm s i \psi}\, {}_sY_{\ell m}(\hat{n})$$

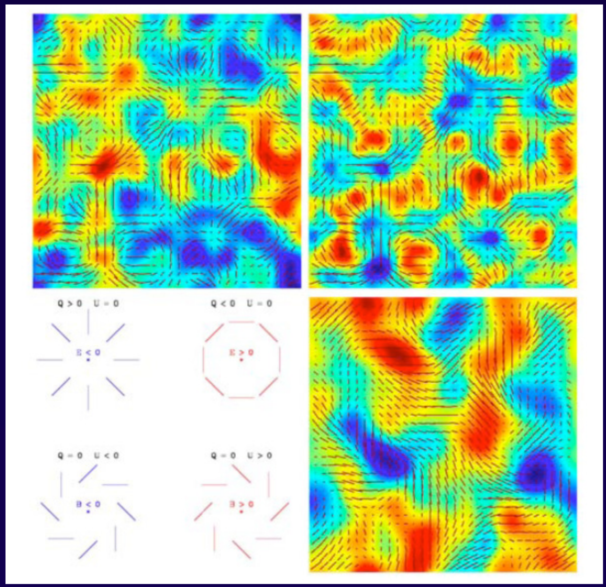
The polarization of the CMB (II)

- Polarization maps can be decomposed into two scalar fields usually called **E-modes** (analog of the gradient component) and **B-modes** (analog of the curl component). Kamionkowski et al. 1997; Seljak & Zaldarriaga 1997.
- These modes are independent of how the coordinate system is oriented and are related to the Q and U (Stokes parameters) by a non-local transformation

$$a_{E,\ell m} = \frac{1}{2}(a_{\ell m}^{+2} + a_{\ell m}^{-2}) \qquad a_{B,\ell m} = \frac{-i}{2}(a_{\ell m}^{+2} - a_{\ell m}^{-2})$$

- **Physics of generation of the Polarization.** Different sources of anisotropies generate different types of modes:

	E-modes	B-modes
Scalar (density perturbations)	Yes	No
Tensor (gravit. waves)	Yes	Yes



Polarization of the CMB (III): power spectra

$$C_{TT} = \frac{1}{2l+1}\sum_m \left\langle a^*_{T,lm}\, a_{T,lm}\right\rangle \qquad C_{BB} = \frac{1}{2l+1}\sum_m \left\langle a^*_{B,lm}\, a_{B,lm}\right\rangle$$

$$C_{EE} = \frac{1}{2l+1}\sum_m \left\langle a^*_{E,lm}\, a_{E,lm}\right\rangle \qquad C_{TE} = \frac{1}{2l+1}\sum_m \left\langle a^*_{T,lm}\, a_{E,lm}\right\rangle$$

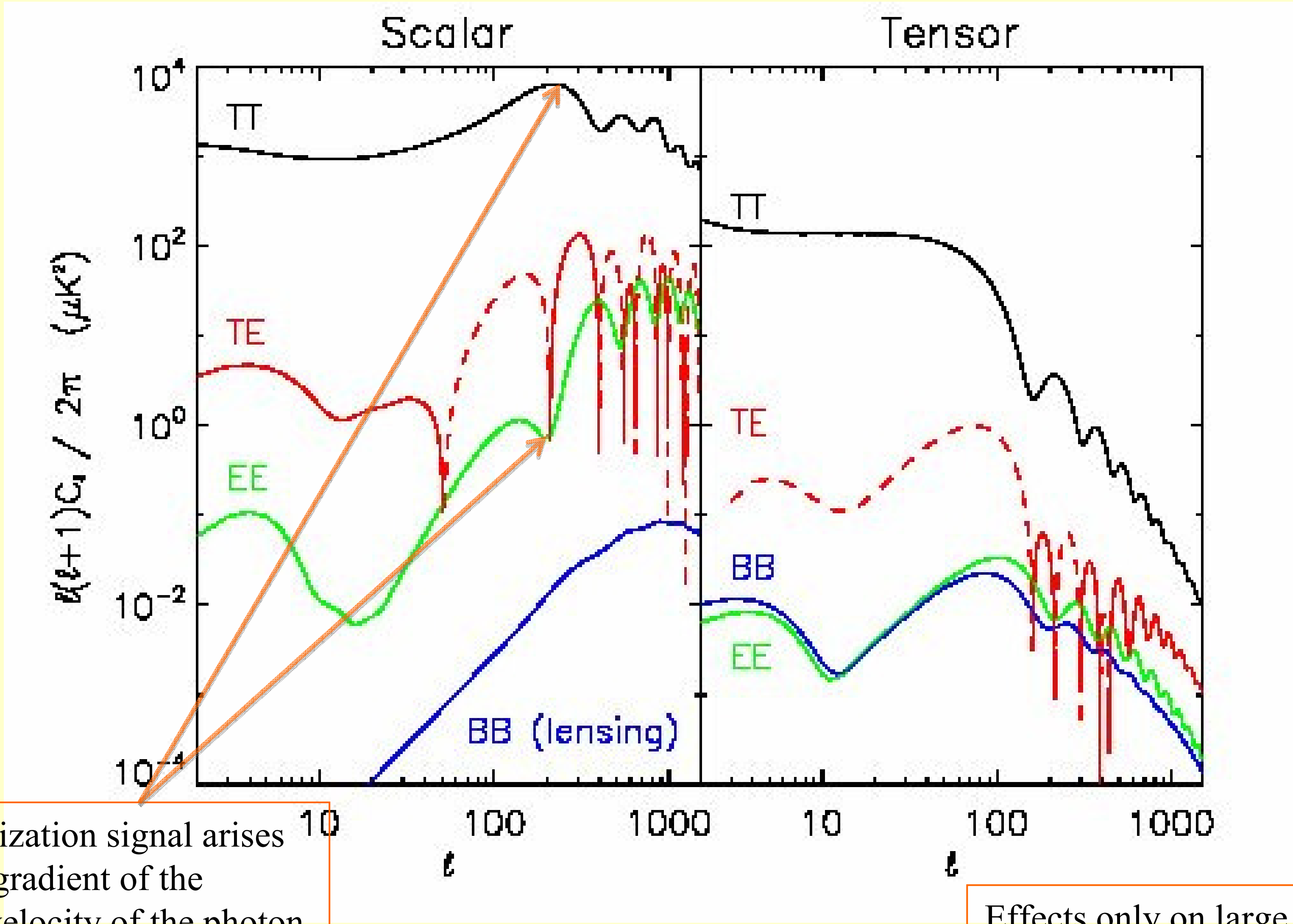
Gravitational Waves produce quadrupolar distorsion of CMB temperatures and induce B-mode polarization

$$C_{El}^{(T)} = (4\pi)^2 \int k^2\, dk\, P_h(k) \left| \int d\tau\, g(\tau)\Psi(k,\tau)\left[-j_l(x) + j_l''(x) + \frac{2j_l(x)}{x^2} + \frac{4j_l'(x)}{x}\right]\right|^2,$$

$$C_{Bl}^{(T)} = (4\pi)^2 \int k^2\, dk\, P_h(k) \left| \int d\tau\, g(\tau)\Psi(k,\tau)\left[2j_l'(x) + \frac{4j_l}{x}\right]\right|^2,$$

(Seljak & Zaldarriaga 1997)

Power spectra - Theory

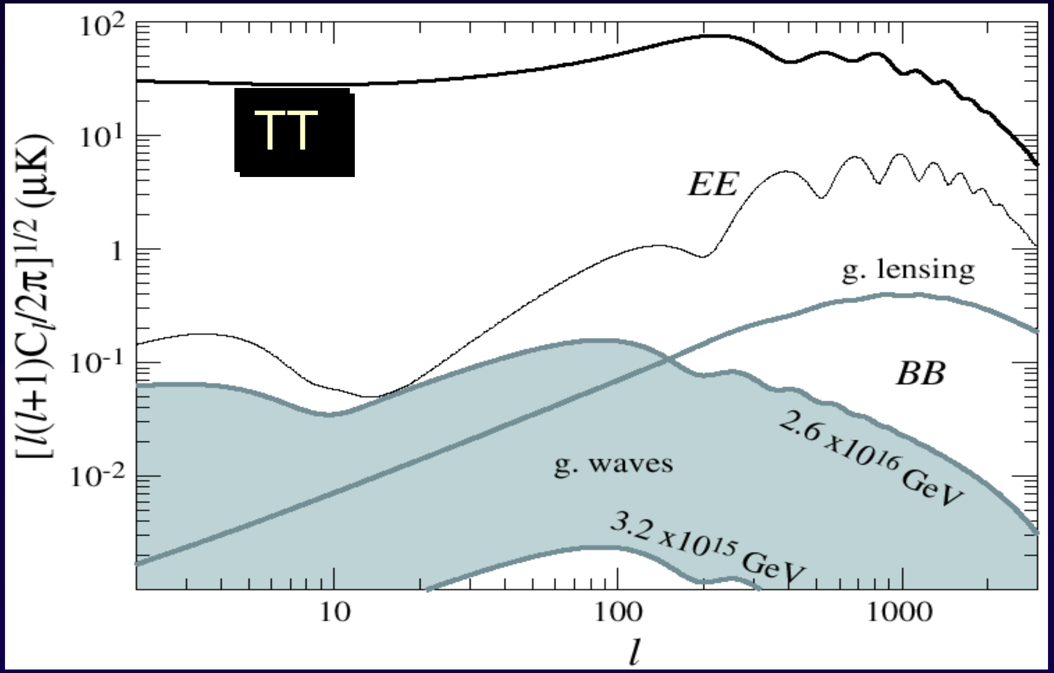


The polarization signal arises from the gradient of the peculiar velocity of the photon fluid => TT and EE peaks are out of phase.

Effects only on large scales because gravity waves damp inside horizon.

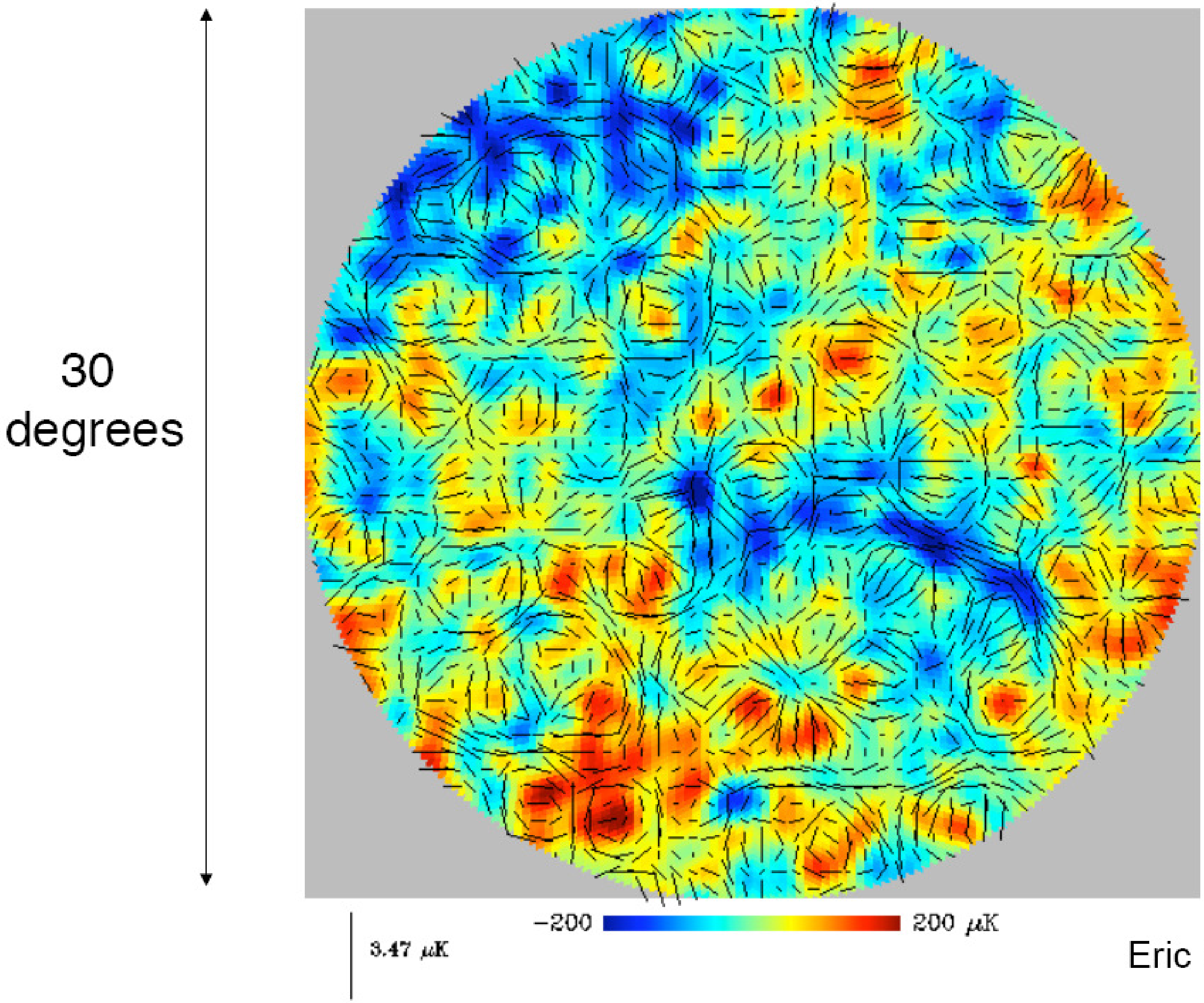
B-modes

Caused by the differential stretching of spacetime associated with a background of primordial GWs



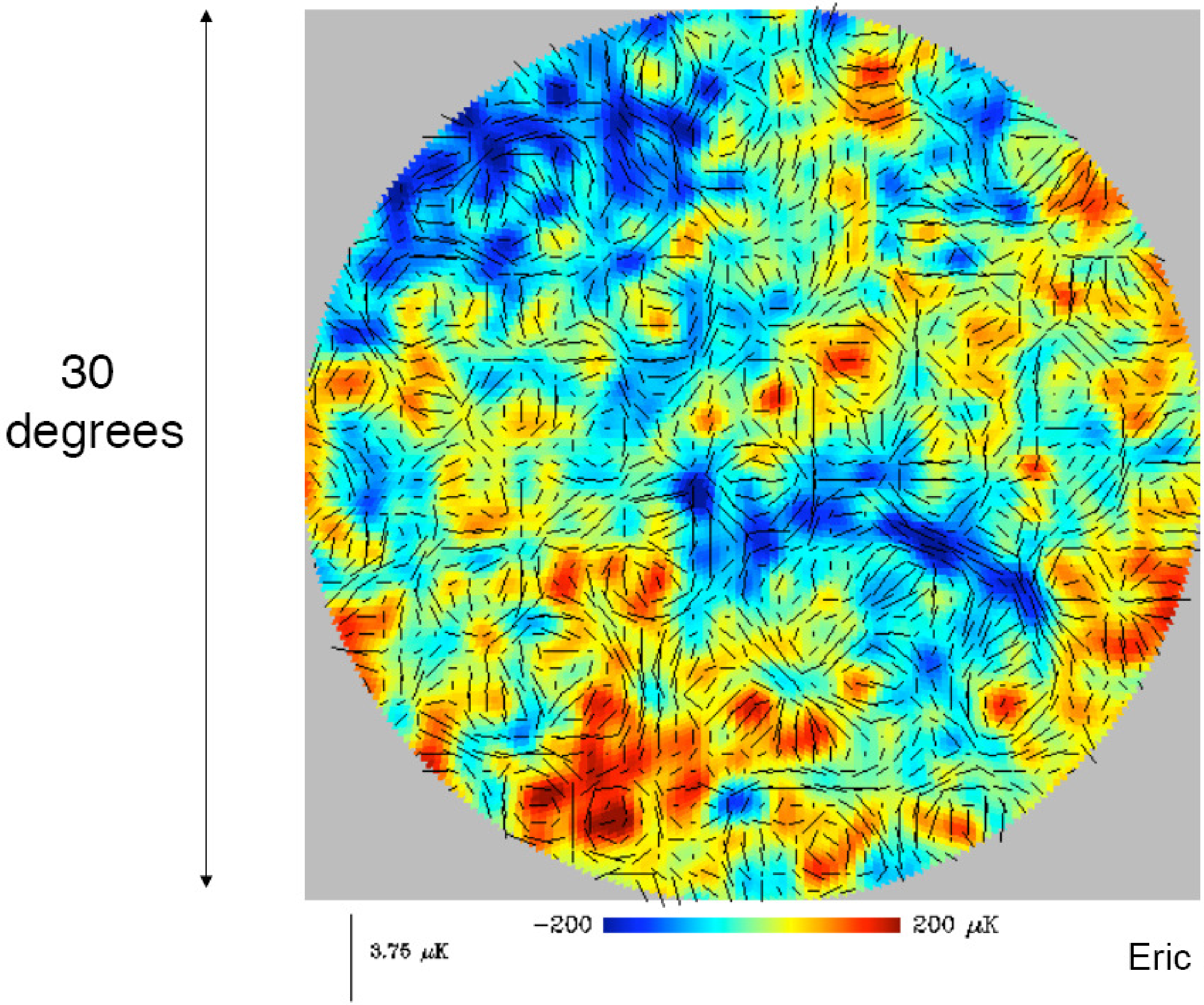
- **r=T/S** is proportional to the energy scale of inflation, which is proportional to the density of primordial gravitational waves.
- r=0.1 corresponds to an energy scale of inflation around the expected GUT scale.

No gravitational waves (r = 0)



Eric Hivon

Gravitational waves (r = 0.3)



Eric Hivon

Main reasons to measure CMB polarization

a) break degeneracy between cosmological parameters and improve accuracy of constraints

b) provide an independent test of the basic assumptions that underlay the standard cosmological model

c) the detection of primordial gravitational waves

CMB Polarization experiments

Ground-based:

- CAPMAP
- DASI
- Polatron
- BICEP
- QUAD
- QUIET
- ACT
- QUIJOTE

- CBI
- KuPID
- AMiBA
- PolarBear
- ClOVER

Balloon:

- Archeops
- BOOMERanG
- MAXIPOL
- EBEX
- SPIDER
- SPUD

Space:

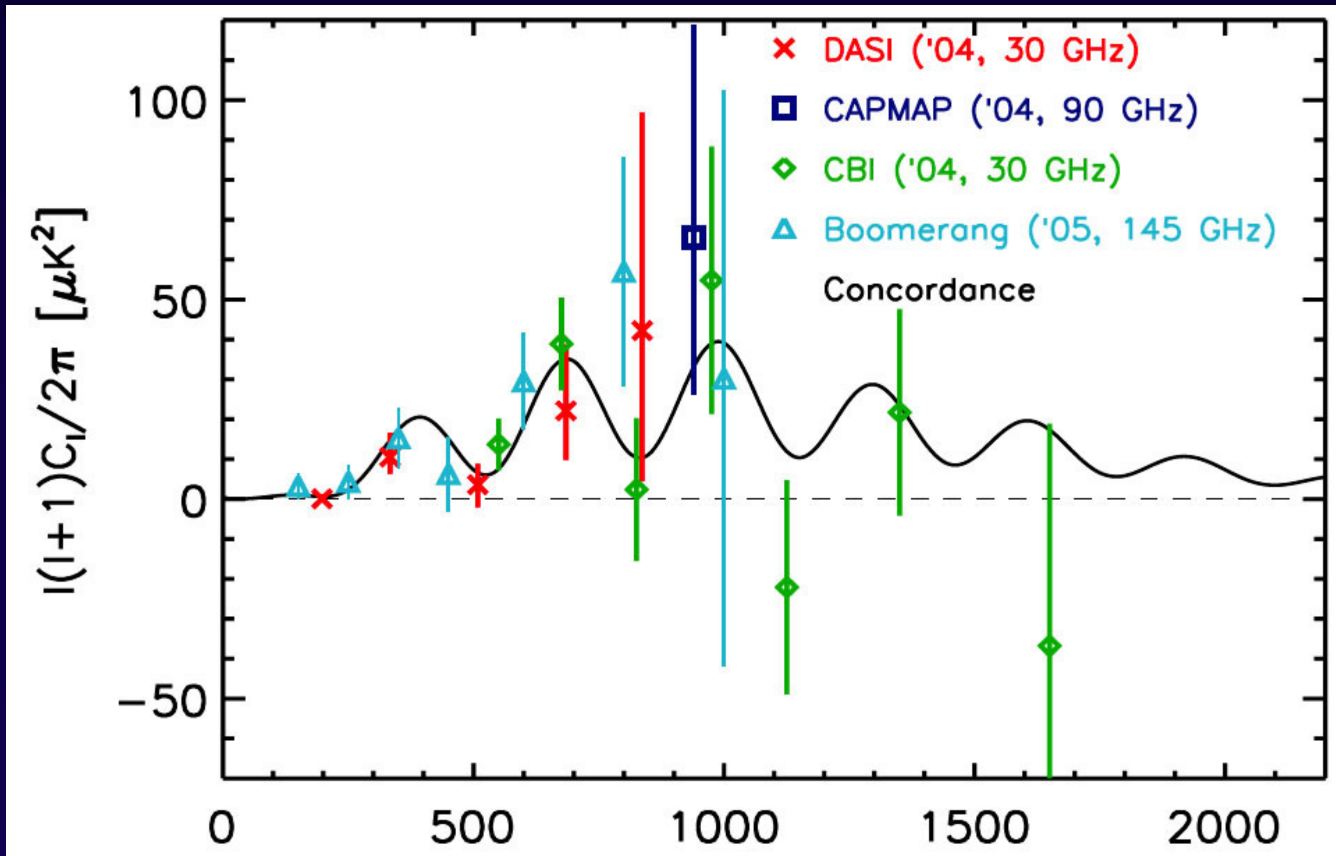
- WMAP
- Planck
- B-Pol-CORE
- CMB-Pol

E-modes

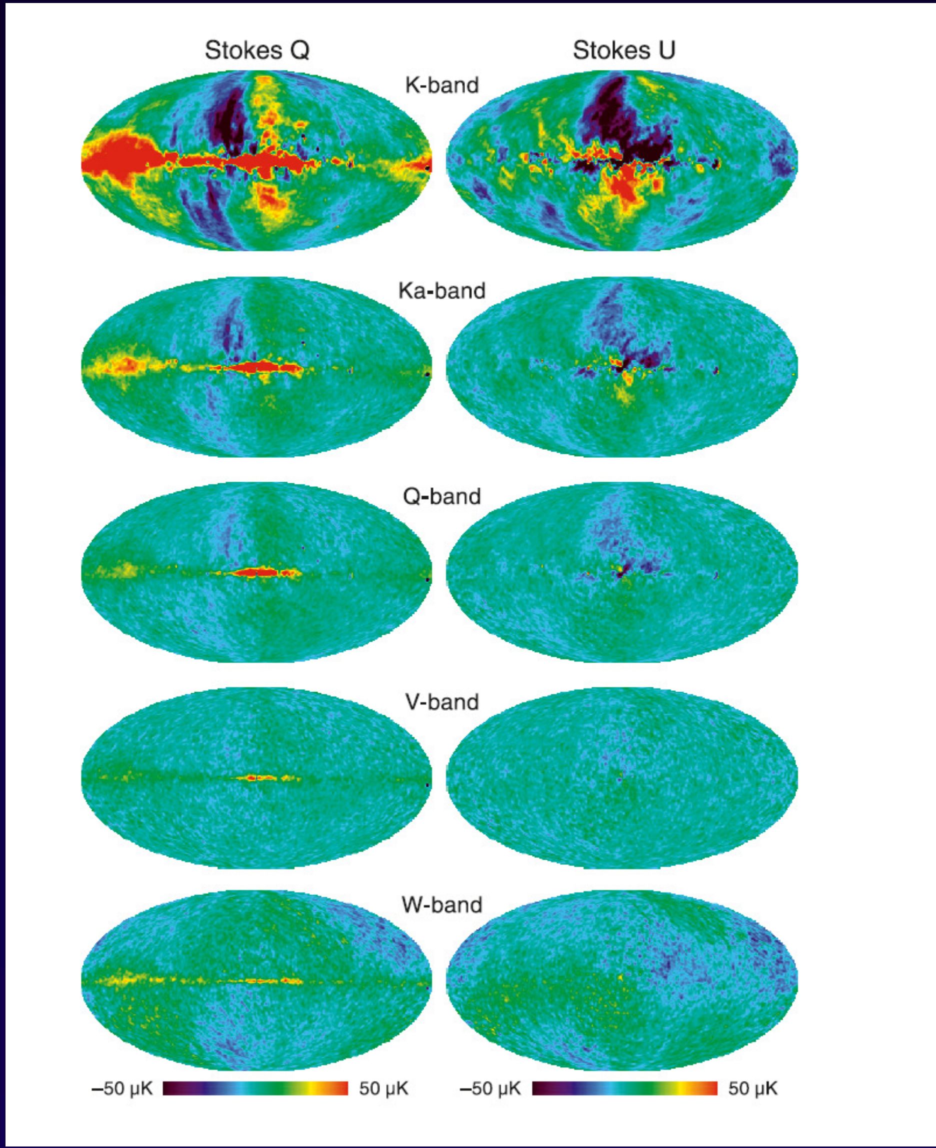
- Detected at a high level of significance
- Generated by density perturbations at recombination are tightly correlated with the temperature anisotropies in the CMB.

First Observations of CMB polarization

- *E-mode detections: DASI (Kovac et al. 2002, Nature) WMAP, CAPMAP, CBI, Boomerang,*

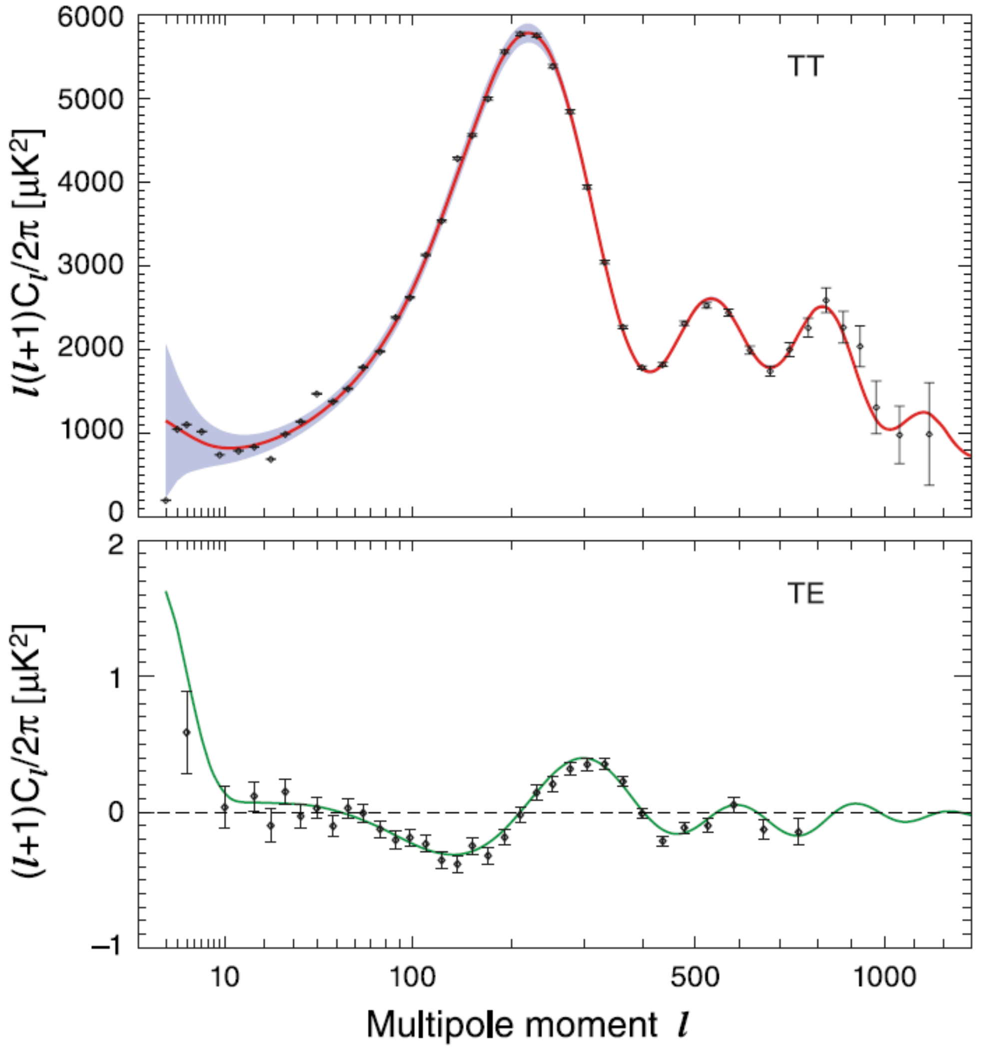


Polarization results from WMAP 7yr



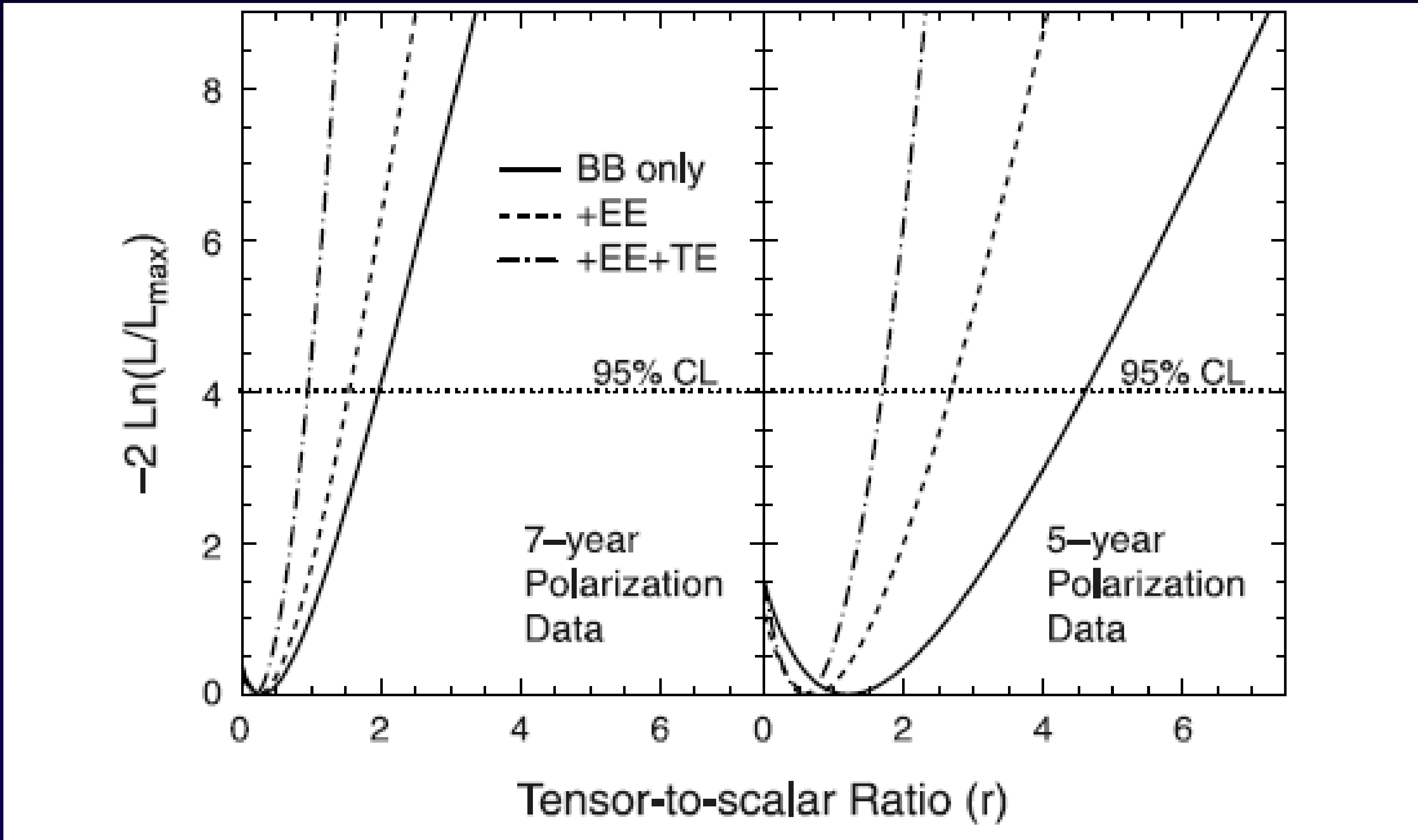
Jarosik et al .2010

WMAP 7-yr



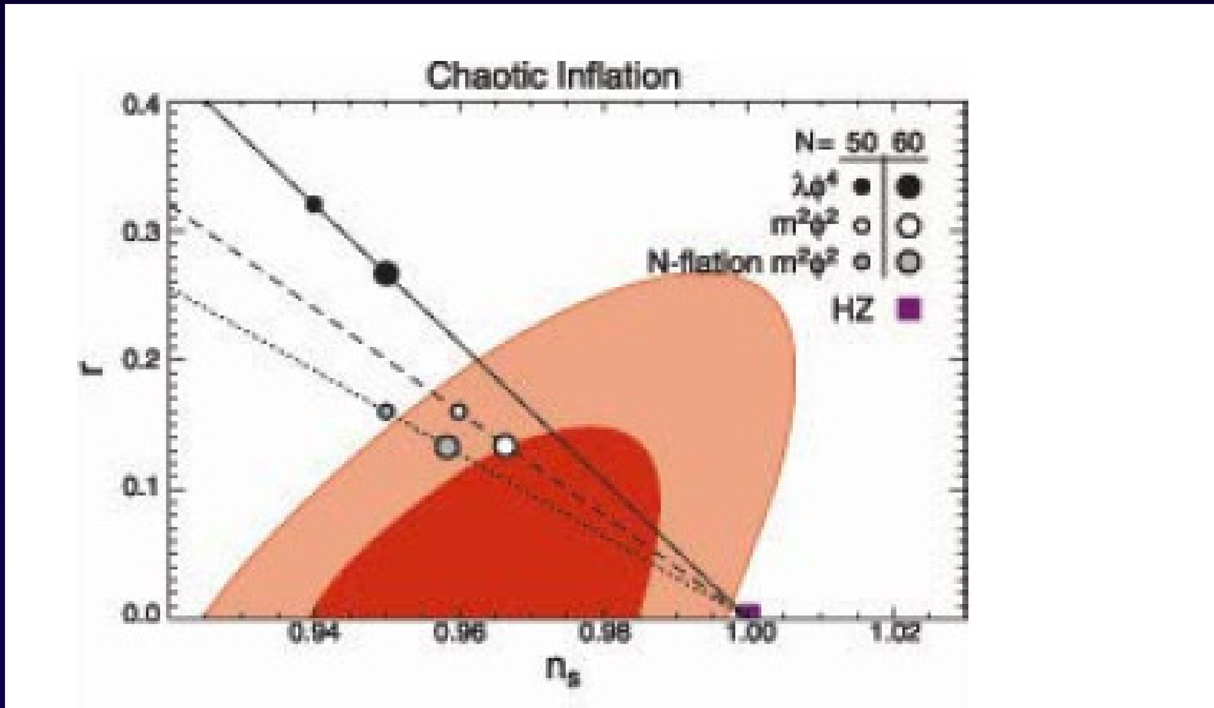
TT
TE
6000
5000
4000
3000
2000
1000
0
2
1
0
–1
10
100
500
1000
Multipole moment l
$l(l+1)C_l/2\pi$ [μK^2]
$(l+1)C_l/2\pi$ [μK^2]

Constraints on r from WMAP 7-yr



Komatsu et al. 2010

Chaotic single field Inflation with Φ^4 is ruled out



Constraints from WMAP+ Acoustic Baryon Oscillations + SNe

Komatsu et al. 2010 → r <0.2 ,, 95% C.L.

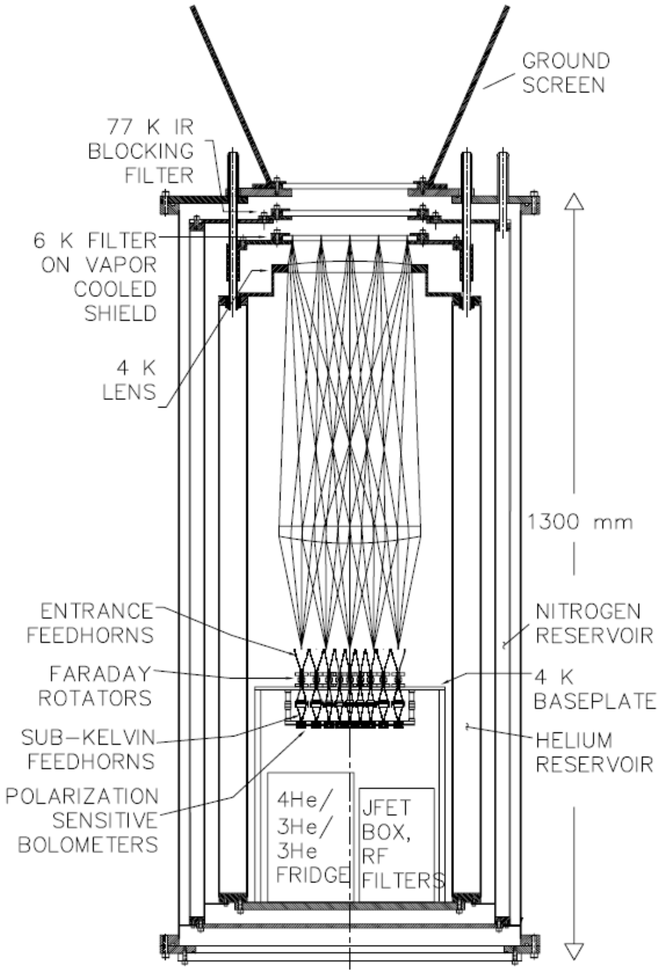
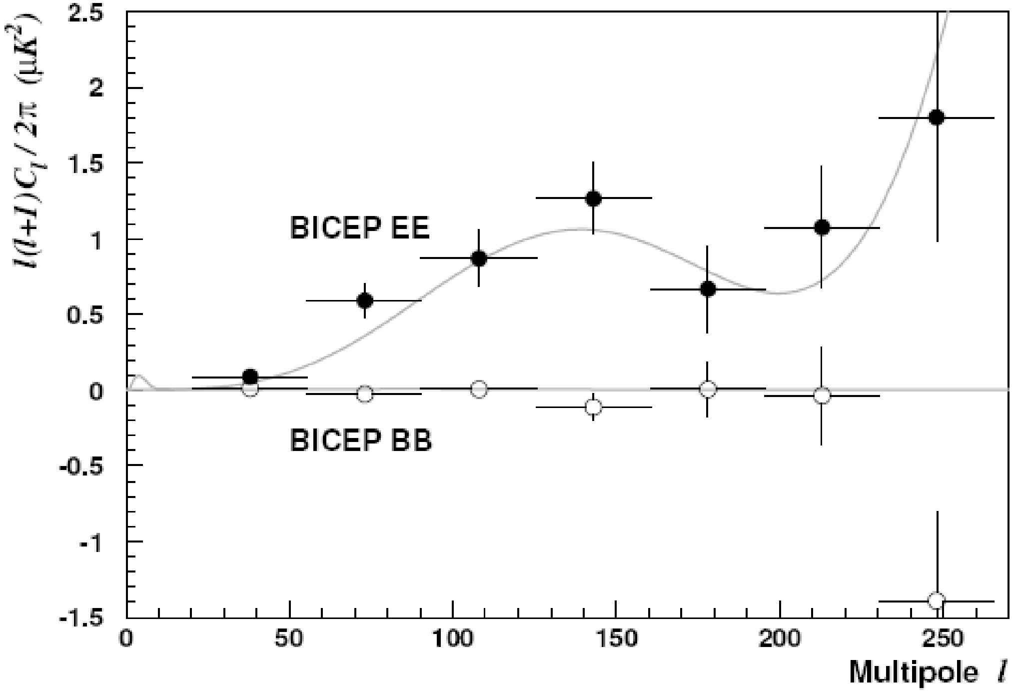
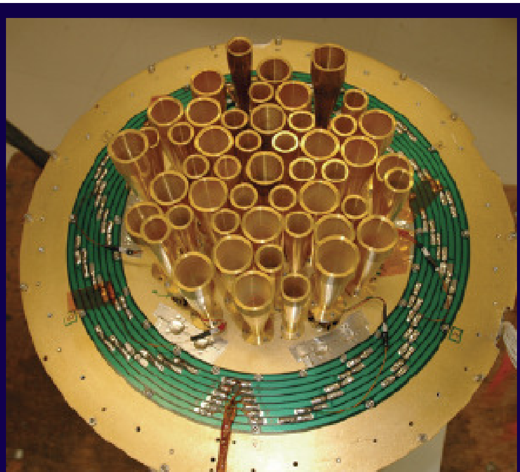


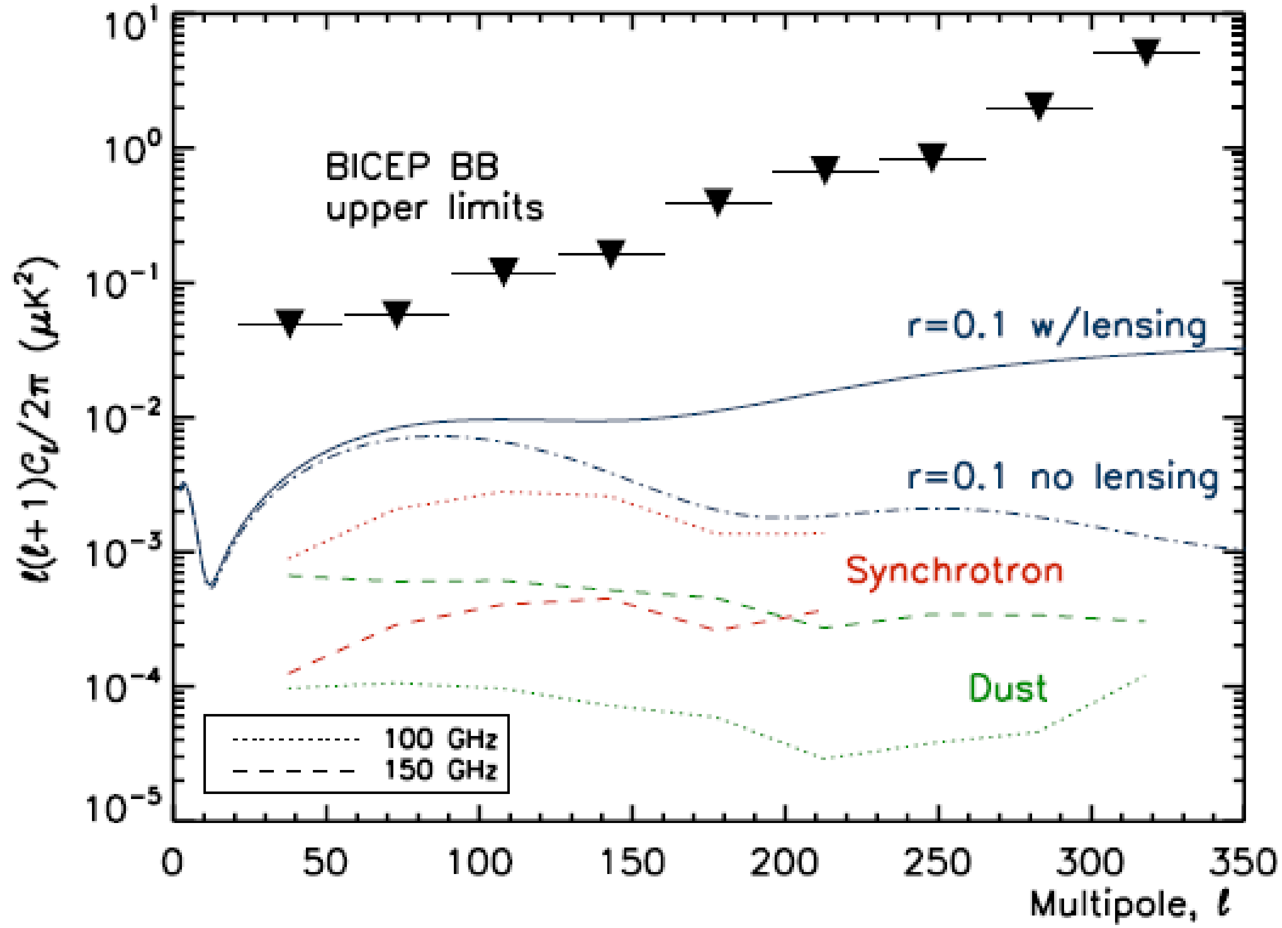
Figure 3. BICEP instrument. See text for complete discussion.





BICEP at South Pole Chiang et al. 2010

BICEP



r<0.72 (95% C.L.) using BB spectrum only *(Chiang et al.)*

Recent observations of CMB polarization

CMB POLARIZATION SPECTRA FROM BICEP TWO-YEAR DATA 17

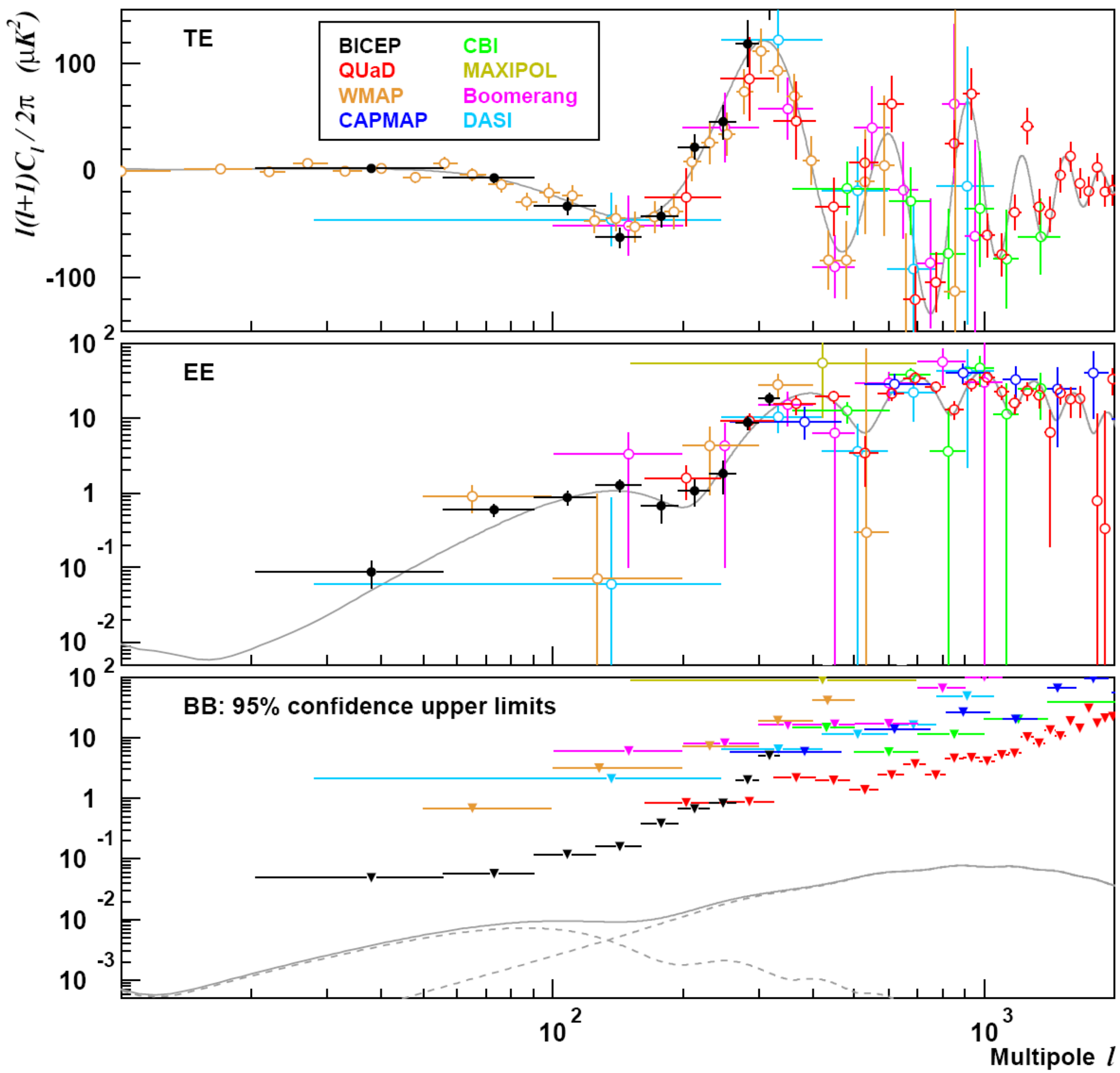
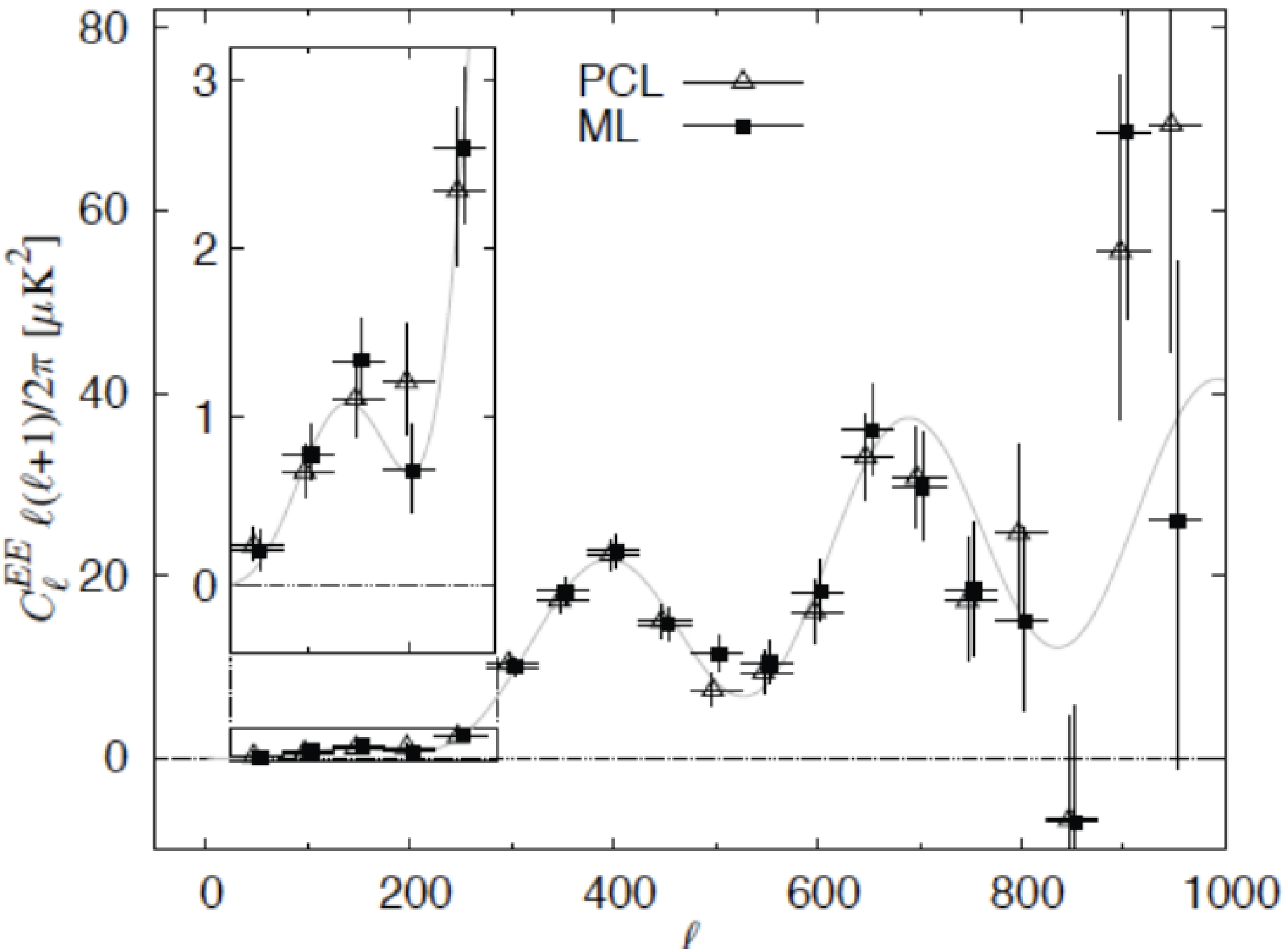


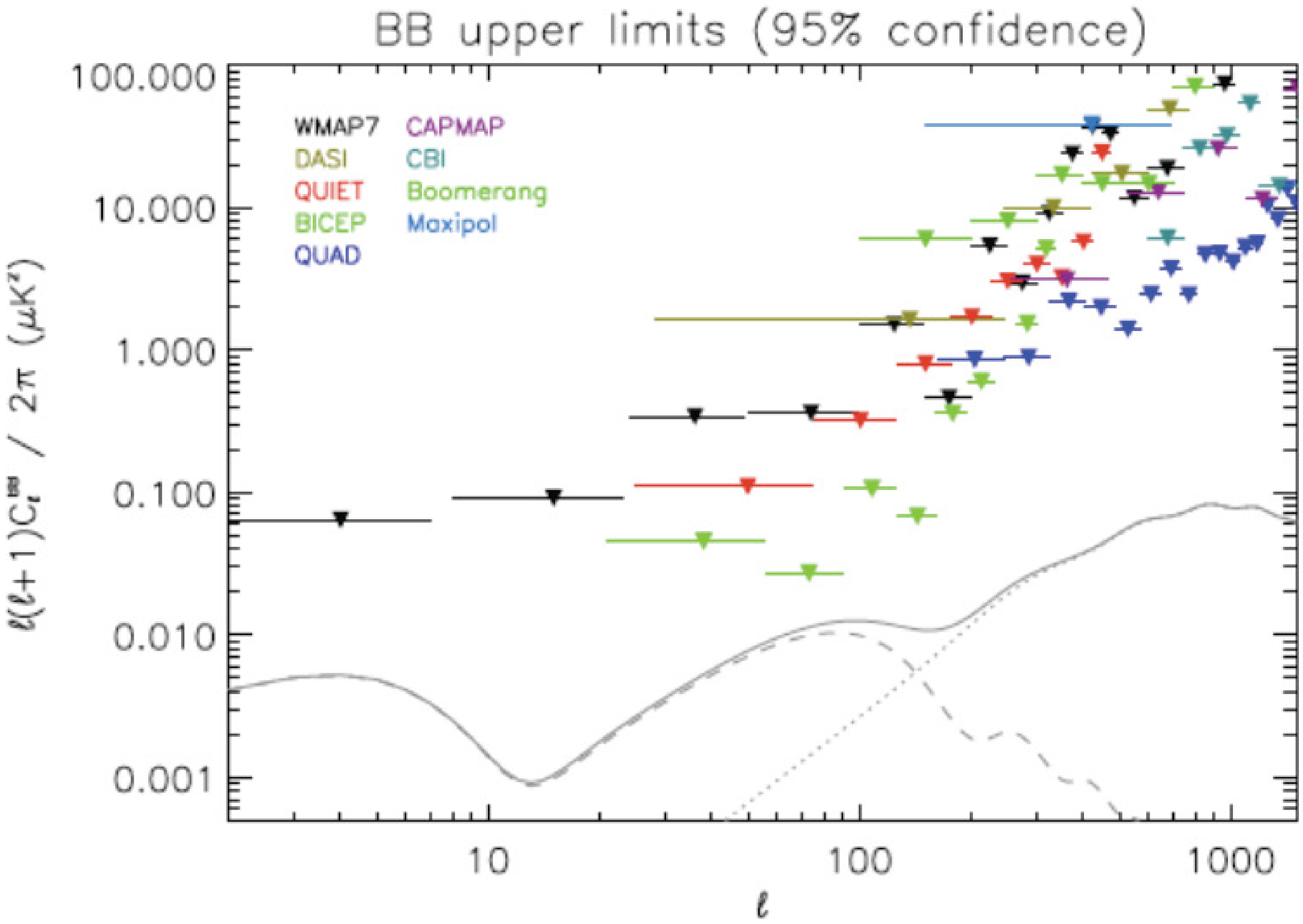
FIG. 13.— BICEP's TE, EE, and BB power spectra complement existing data from other CMB polarization experiments (Leitch et al. 2005; Montroy et al. 2006; Piacentini et al. 2006; Sievers et al. 2007; Wu et al. 2007; Bischoff et al. 2008; Nolta et al. 2009; Brown et al. 2009). Theoretical spectra from a ΛCDM model with $r = 0.1$ are shown for comparison; the BB curve is the sum of the inflationary and gravitational lensing components. At degree angular scales, BICEP's constraints on BB are the most powerful to date.

Chiang et al. 2010

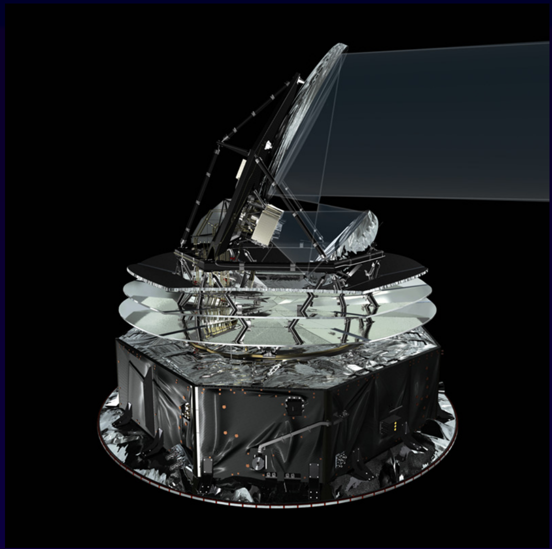
QUIET results at 95 GHz



CMB polarization. BB spectrum



Planck



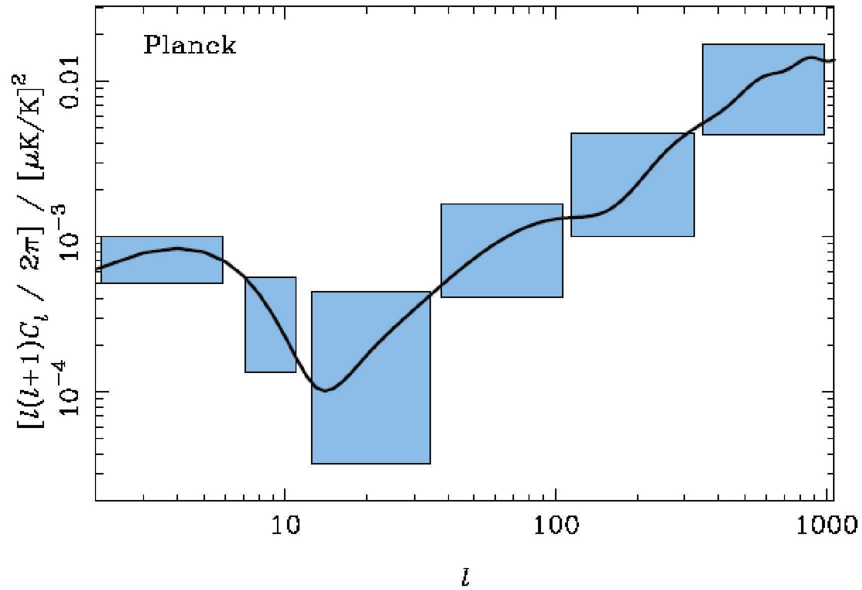


FIG 2.17.—Forecasts for the $\pm1\sigma$ errors on the B-mode polarization power spectrum C_ℓ^B from *Planck* (for $r = 0.1$ and $\tau = 0.17$). Above $\ell \sim 150$ the primary spectrum is swamped by weak gravitational lensing of the E-polarization produced by the dominant scalar perturbations. The cosmological model, and the assumptions about instrument characteristics, are the same as in Figure 2.13.

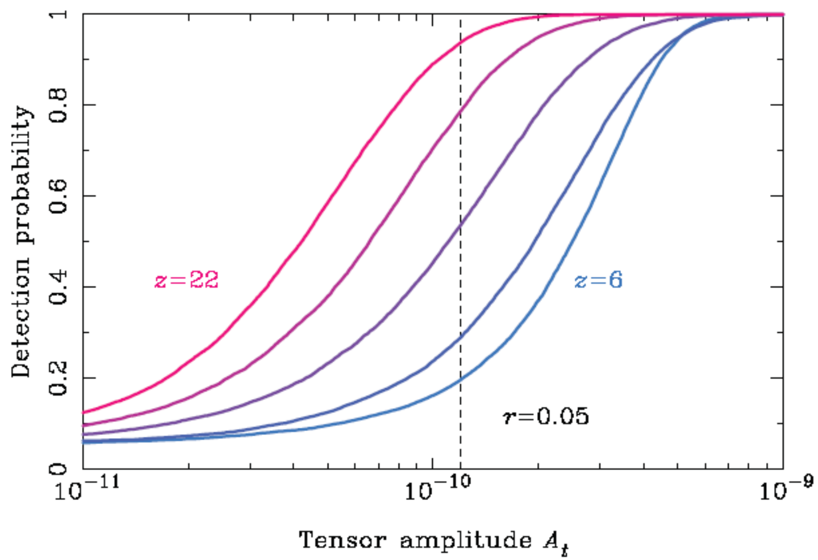
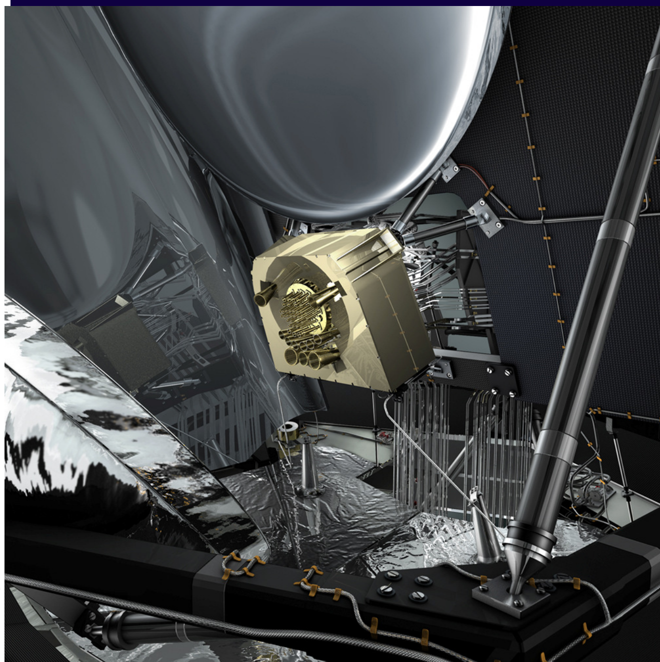
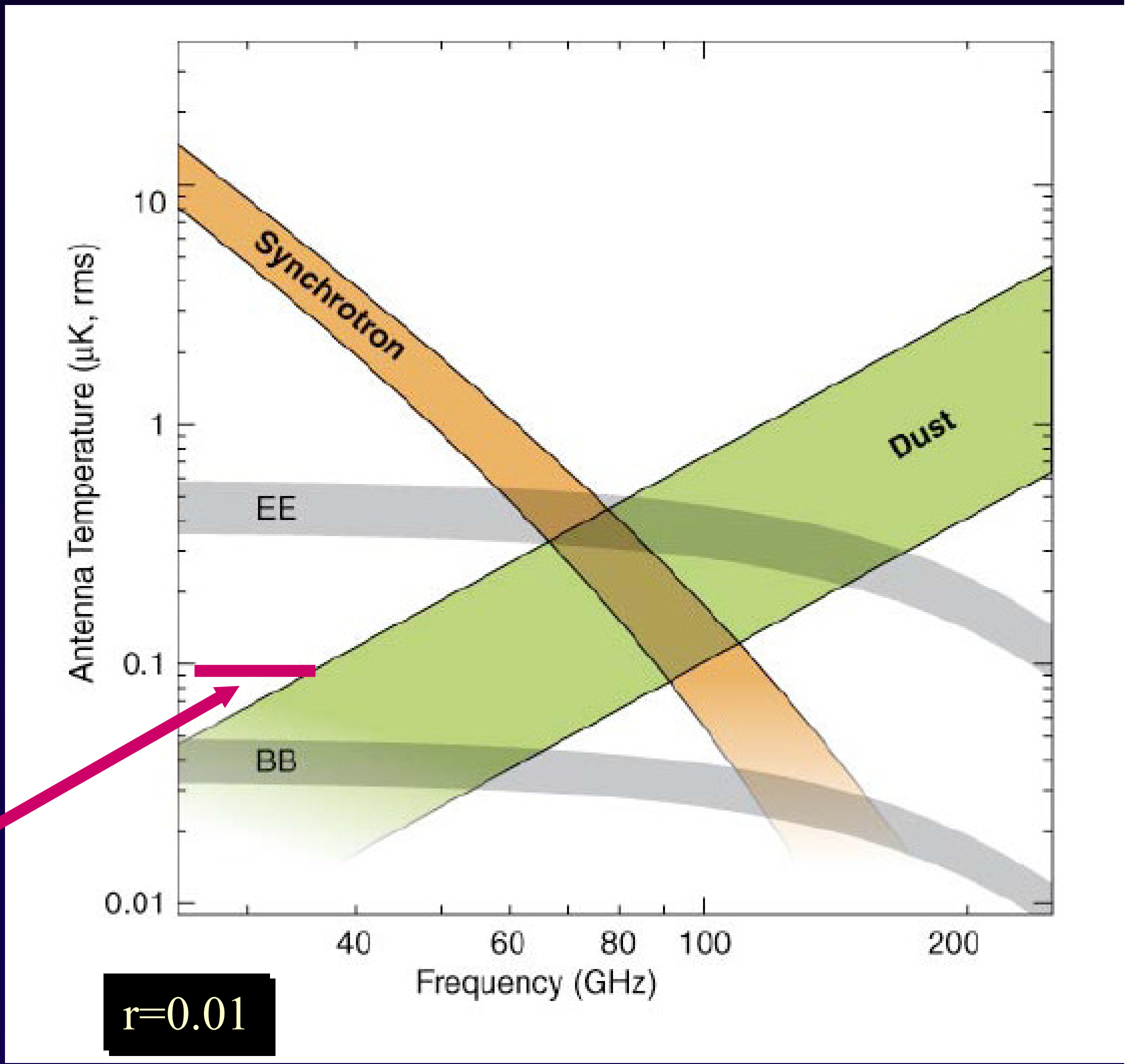


FIG 2.16.—The probability of detecting B-mode polarization at 95% confidence as a function of A_T, the amplitude of the primordial tensor power spectrum (assumed scale-invariant), for *Planck* observations using 65% of the sky. The curves correspond to different assumed epochs of (instantaneous) reionization: $z = 6$, 10, 14, 18 and 22. The dashed line corresponds to a tensor-to-scalar ratio $r = 0.05$ for the best-fit scalar normalisation, $A_S = 2.7\times10^{-9}$, from the one-year *WMAP* observations.



Observability of B-modes

- **Critical issues**:
  - Signals are extremely small. Need for large number of receivers and large bandwidths.
  - Control on systematics (spillover, cross-pol, beam polarization purity, instrumental polarization,etc).
  - Foregrounds. B-modes are never dominant over galactic foregrounds.



The QUIJOTE CMB Experiment

(Q-U-I JOint TEnerife Cosmic Microwave Background Experiment)

(http://www.iac.es/project/cmb/quijote)

The QUIJOTE CMB Experiment

INSTITUTO DE ASTROFISICA DE CANARIAS · IAC

IFCA — Instituto de Física de Cantabria

DICOM

idom

Jodrell Bank Observatory

UNIVERSITY OF CAMBRIDGE

- **Aim**: To perform high sensitivity observations of the polarization of the CMB, Galactic and extragalactic foregrounds in the frequency range 10-41 GHz at large angular scales (one degree resolution). Reach the B-mode domain $r<0.05$.

The QUIJOTE CMB consortium

Instituto de Astrofísica de Canarias

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The QUIJOTE CMB Experiment

(Q-U-I JOint TEnerife Cosmic Microwave Background Experiment)

- QUIJOTE is a collaborative project between IAC, IFCA (CSIC-UC), DICOM (UC), IDOM, Jodrell-Bank Observatory (Univ. of Manchester, UK) and Cavendish Laboratory (Univ. Cambridge, UK) .
- **Aim**: To perform high sensitivity observations of the polarization of the CMB and Galactic emissions in the frequency range 10-42 GHz at large angular scales (one degree resolution).
- Major funding (80%) is provided by Spanish National Research Programmes (PNAYA, PNE and the Consolider Ingenio project "Exploring the Physics of Inflation")

Quijote Science goals

- Search for a signature of gravitational B-modes (amplitude r ~0.05)
  - In combination with Planck push limits beyond r=0.05
- Measurement of the E-mode angular power spectrum: Cosmological parameters
- Characterize foregrounds with unprecedented sensitivity in the 10-30 GHz range (needed to correct future space missions like CORE aiming to reach r=0.001)

QUIJOTE: Project basic features

- **Site**: Teide Observatory
- **Frequencies**: 11, 13, 17, 19, 30 and 41 GHz.
- **Angular resolution**: ~1 degree
- **Telescopes and instruments:**
  - **Phase I (funded) .** First telescope with a multichannel instrument providing 10-20 GHz (starts operation this summer), and a second instrument with 31 polarimeters @ 30 GHz (shall be completed in 2013) . A polarised source subtractor will also start operation in summer 2012.
  - **Phase II (funded)** via the Consolider Ingenio programme "Exploring the Physics of Inflation" Second telescope (shall be completed at the end of 2012) and third instrument with 40 polarimeters at 41 GHz (shall be completed in 2014).
  - **Scientific operation plan: 2012-2016 approved (aimed extension for another 4 years)**
  - **Phase III.** New concepts (30GHz-90GHz) /replicate at Southern Hemisphere

Observatorio del Teide
(http://www.iac.es)

Altitude: 2400 m

Longitude: 16º 30’ W

Latitude: 28º 17’ N

Typical PWV: 1-3 mm

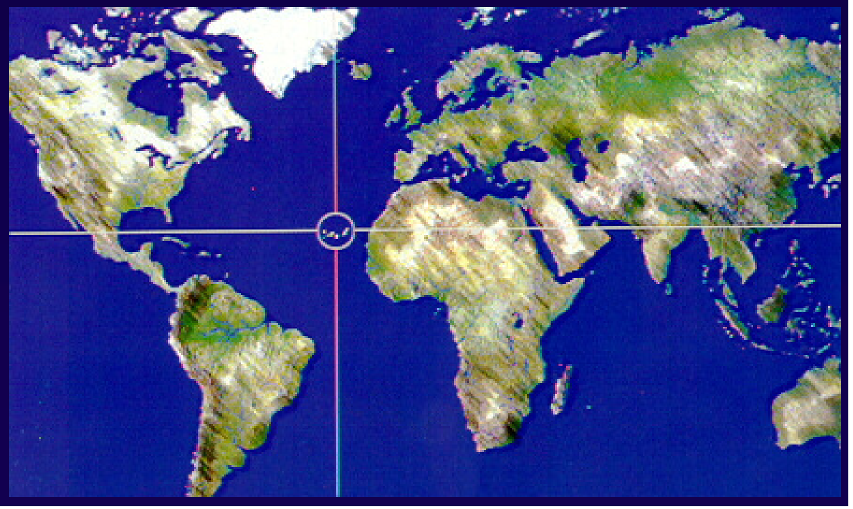
Transmissivity: 98%
$\equiv \; T_{sky} \approx 5$ K

Good weather: 80%

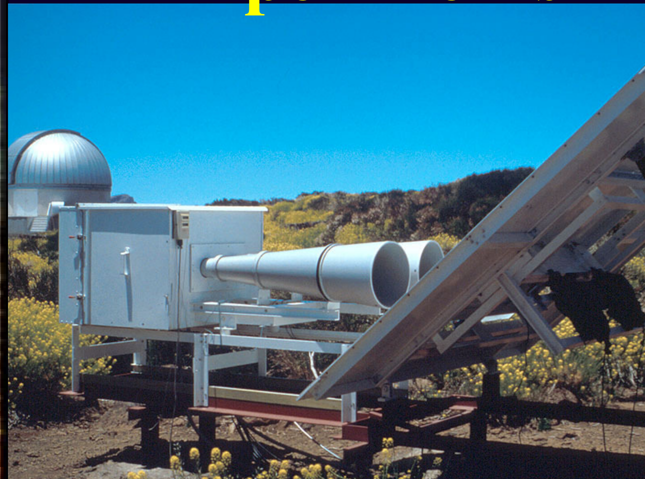
Easy access: 40 km road journey from IAC

The Teide Observatory site run by the Instituto de Astrofisica de Canarias (IAC) and is above much of the atmospheric water vapour with a stable dry climate.

Our previous experience with CMB experiments (Tenerife, VSA, COSMOSOMAS) shows that 80% of the time the data is just system noise limited.



First CMB Experiments



Recent CMB experiments at Tenerife

The *Very Small Array*

Cavendish Astrophysics Group
Jodrell Bank Observatory
Instituto de Astrofisica de Canarias

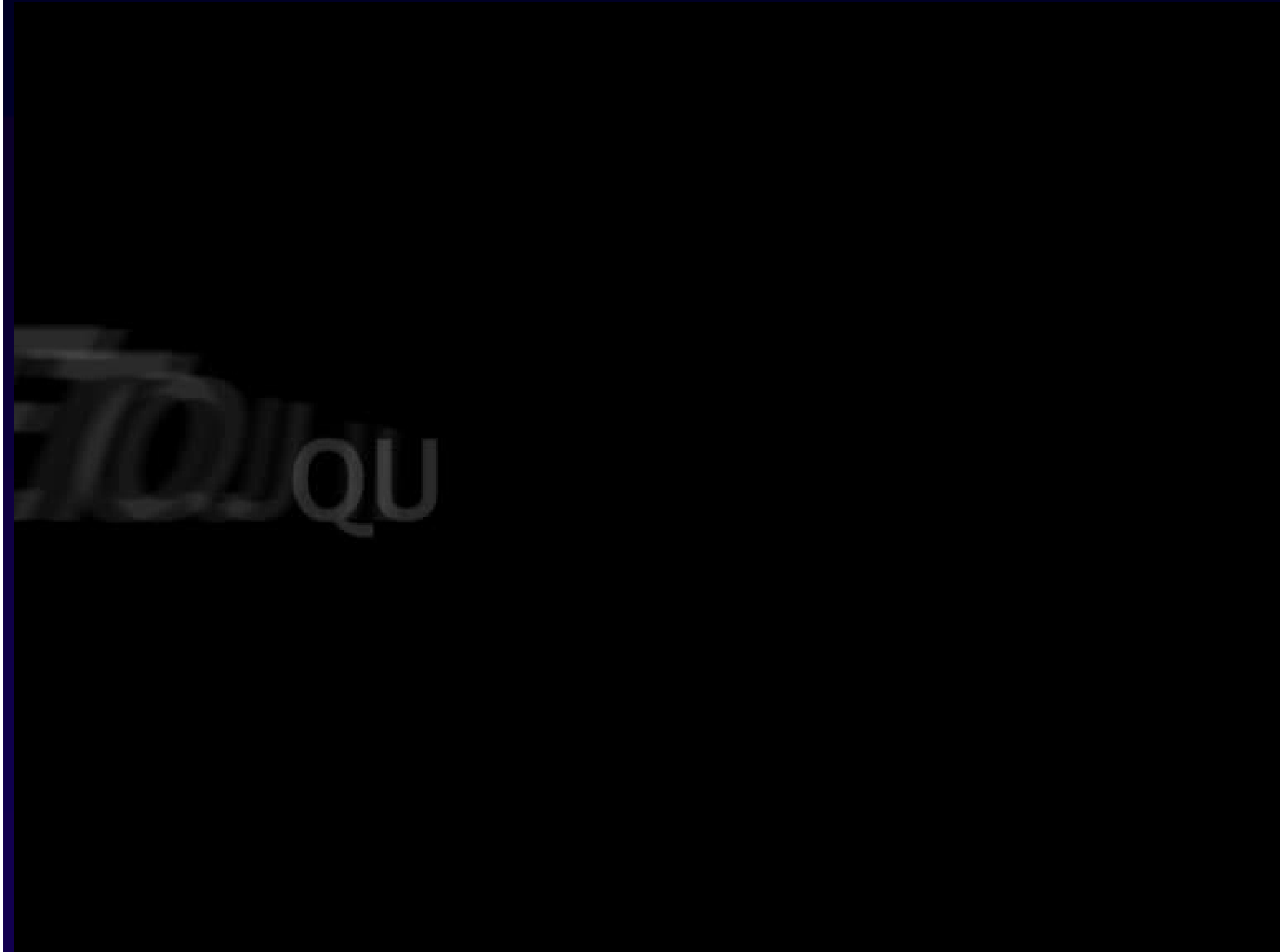
COSMOSOMAS

Instituto de Astrofísica
de
Canarias

11, 13, 15, 17 GHz

Cavendish Astrophysics

Jodrell Bank Observatory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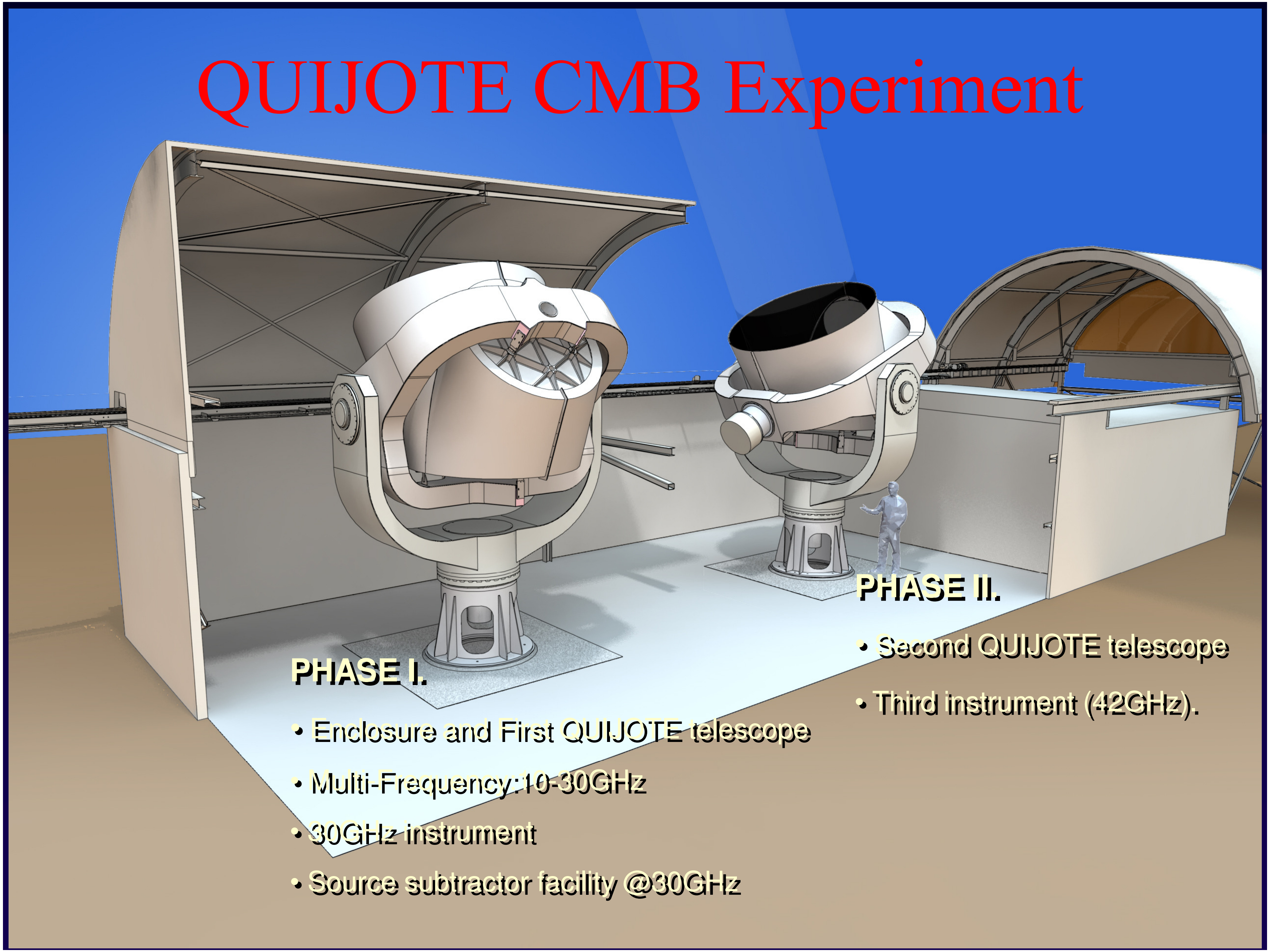
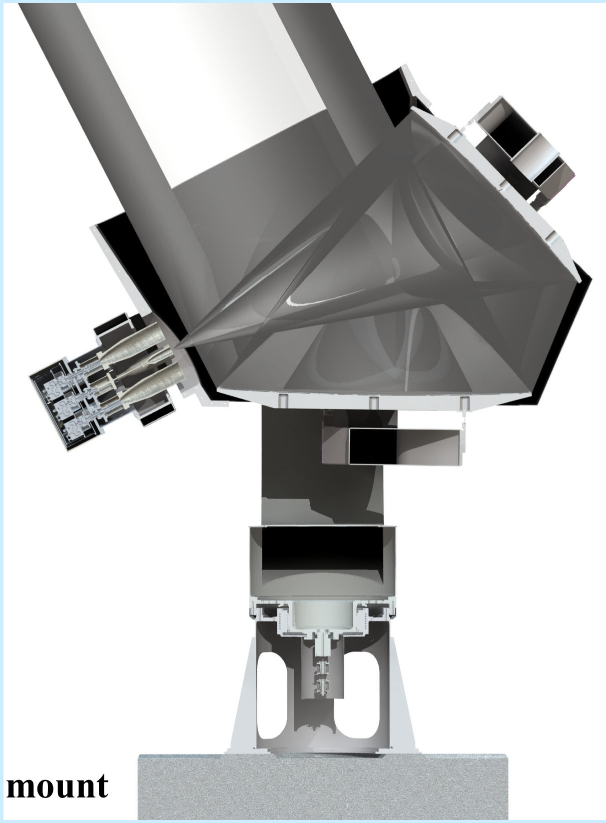
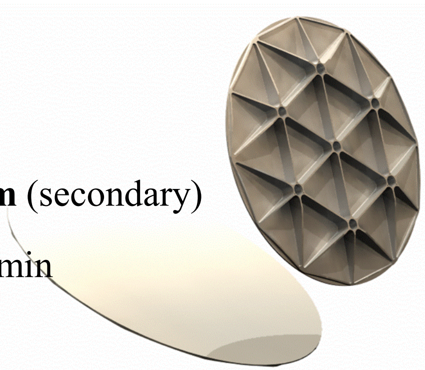
QUIJOTE Enclosure

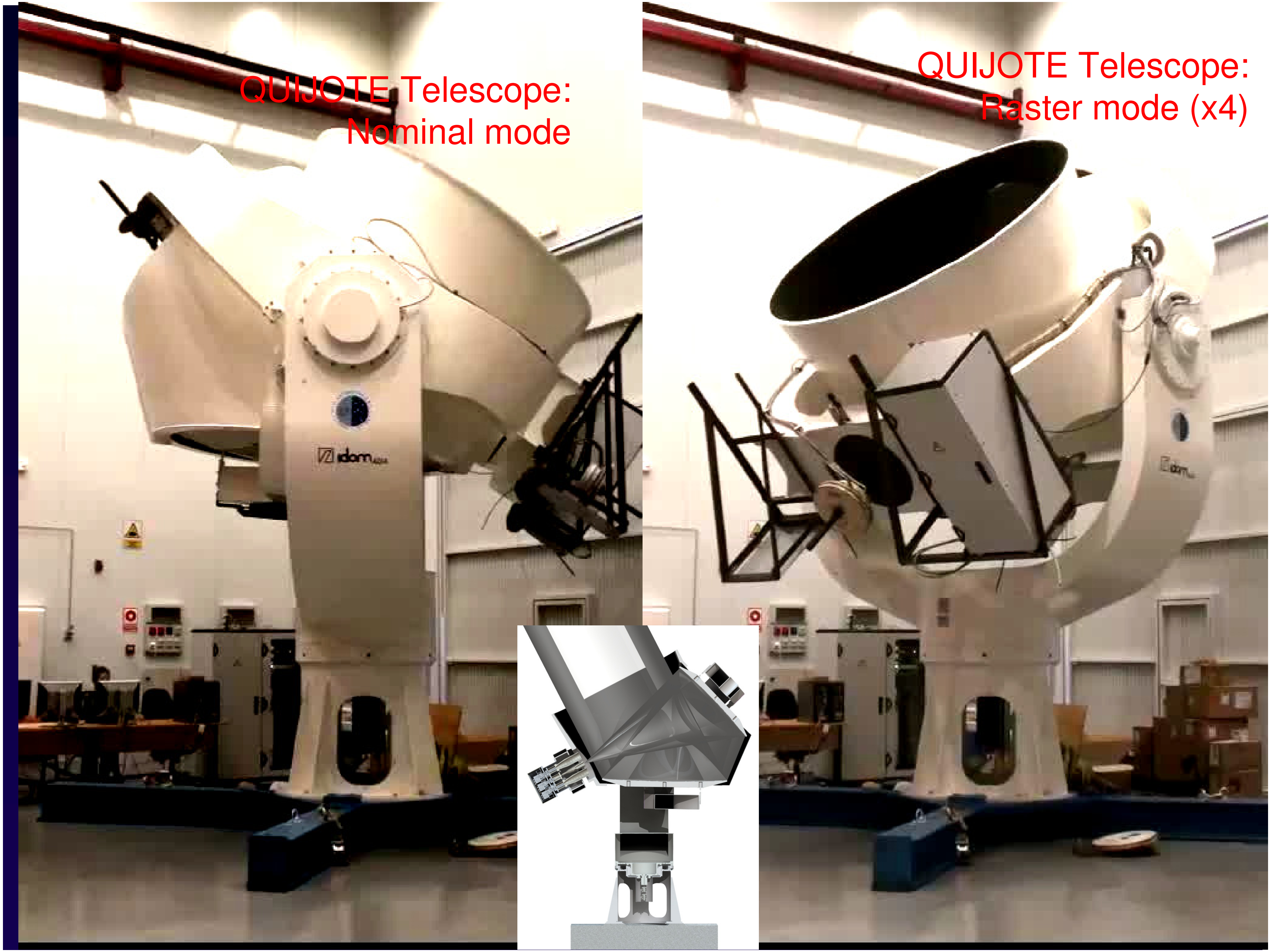

QUIJOTE CMB Experiment
PHASE I.
• Enclosure and First QUIJOTE telescope
• Multi-Frequency:10-30GHz
• 30GHz instrument
• Source subtractor facility @30GHz
PHASE II.
• Second QUIJOTE telescope
• Third instrument (42GHz).

QUIJOTE. Telescope

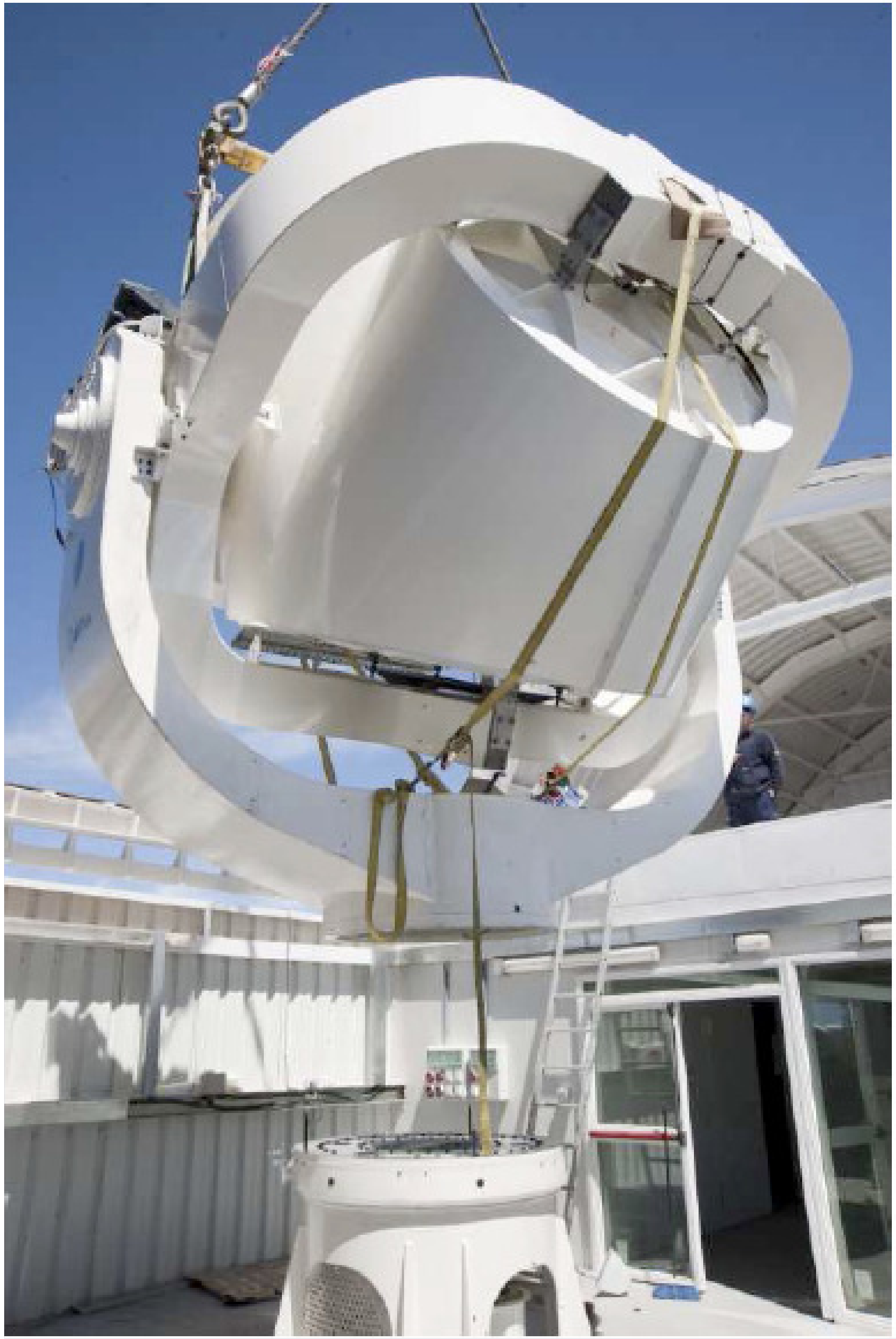


- **Alt-azimutal mount**
- Maximum rotation speed around AZ axis: 0.25 Hz.
- Maximum zenith angle**: 60º**
- **Cross-Dragonian design.**
- Aperture: **2.3 m** (primary) and **1.9 m** (secondary)
- Pointing precission better than 1 arcmin
- Tracking rms <20 arcsec




QUIJOTE Telescope:
Nominal mode
QUIJOTE Telescope:
Raster mode (x4)

First QUIJOTE Telescope (QT1)



Installed at the Teide Observatory in May 3rd, 2012.

QUIJOTE CMB Experiment - Phase I and II. Basic facts

Instrumentation Plan

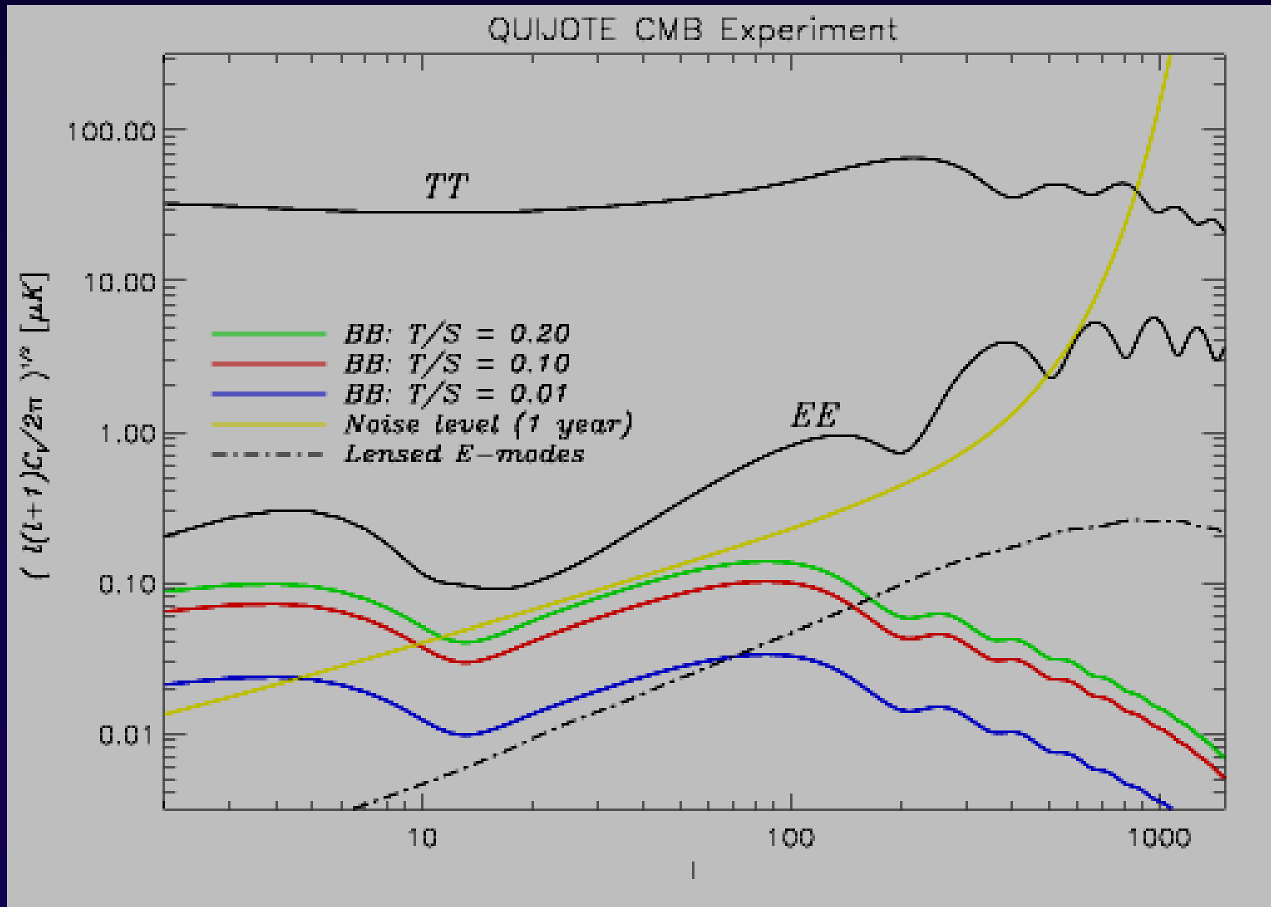
	MFI					TGI	FGI
Nominal Frequency [GHz]	11	13	17	19	30	30	40
Bandwidth [GHz]	2	2	2	2	8	8	10
Number of horns	2	2	2	2	1	31	40
Channels per horn	4	4	4	4	2	4	4
Beam FWHM [°]	0.92	0.92	0.60	0.60	0.37	0.37	0.28
T_{sys} [K]	25	25	25	25	35	35	45
NEP [μK $s^{1/2}$]	280	280	280	280	390	50	50
Sensitivity [Jy $s^{1/2}$]	0.30	0.42	0.31	0.38	0.50	0.06	0.06

- Temperature sensitivity per beam, given by

$$\Delta Q = \Delta U = \sqrt{2}\frac{T_{sys}}{\sqrt{\Delta\nu \times t_{\text{int}} \times N_{chan}}}$$

SCIENCE

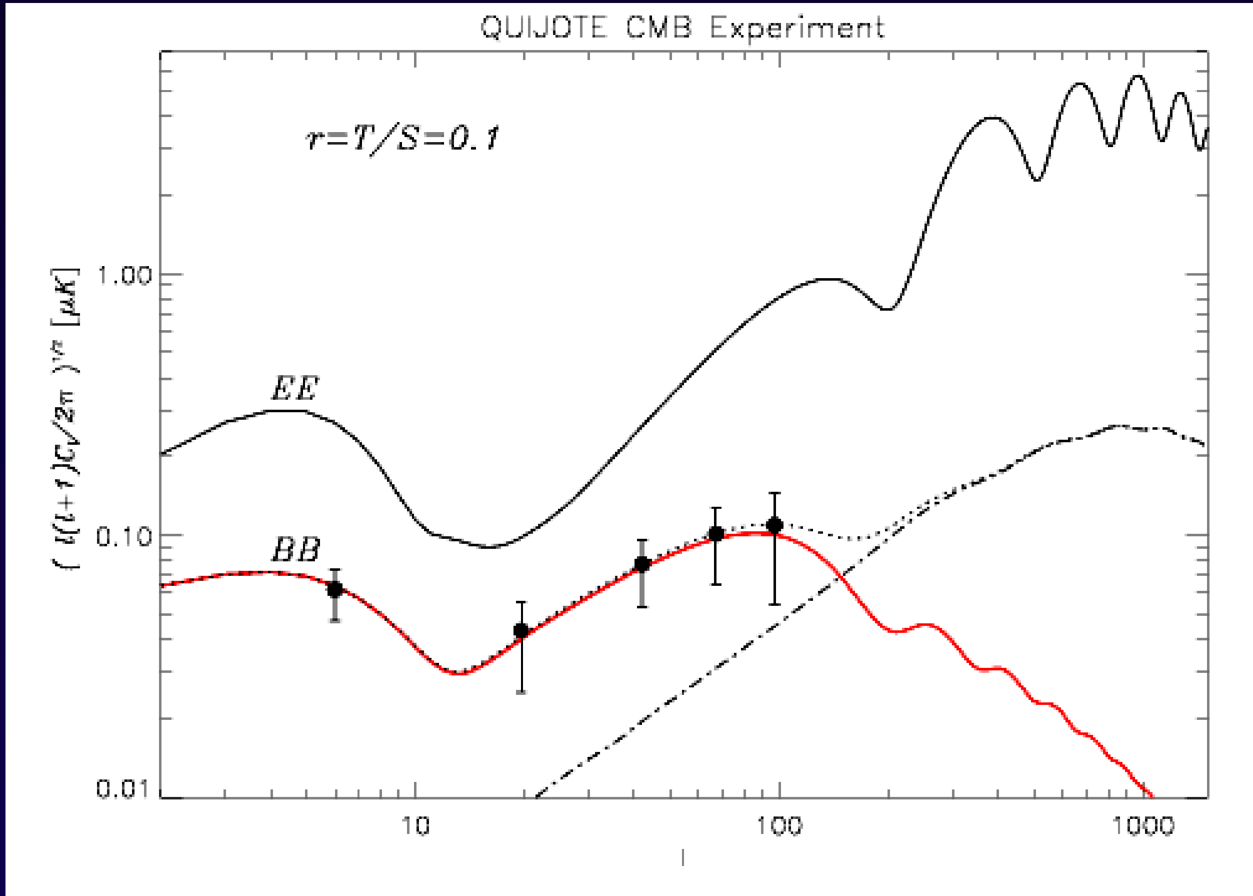
The goal for QUIJOTE (Phase I) is to obtain five polarization maps in the frequency range 10-30 GHz with sufficient sensitivity to correct the 30 GHz map from foreground emission and detect the imprint of B modes with r=0.05



QUIJOTE: Science (phase I)

30 GHz
$\Delta\nu$ = 8 GHz
31 polarim.
N_tel= 1
T_sys= 30 K
FWHM= 1 deg
2 yr eff. integration

0.5μK/beam
Over 5000 sq deg

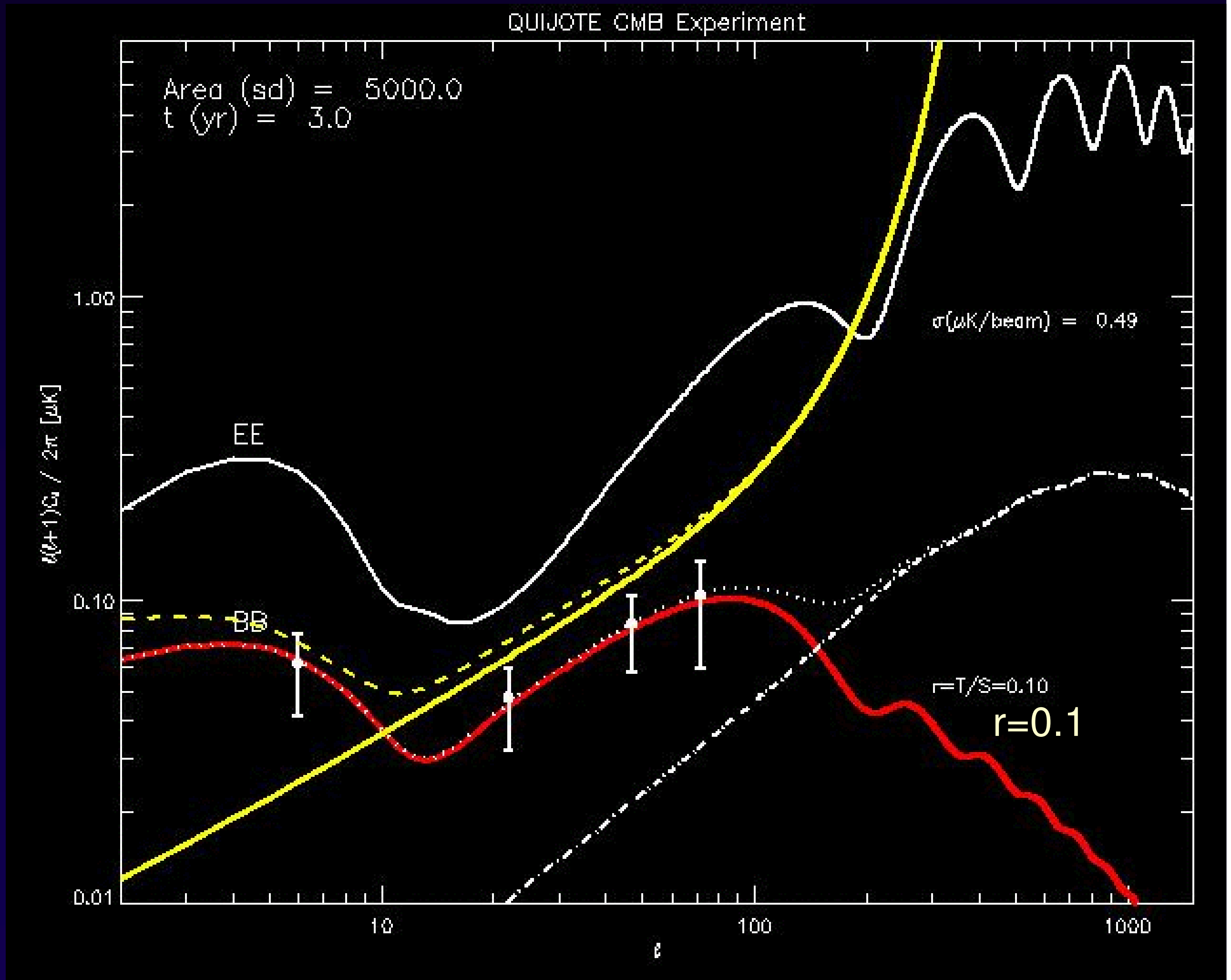


4 sigma detection r=0.1

QUIJOTE: Science (Phase II)

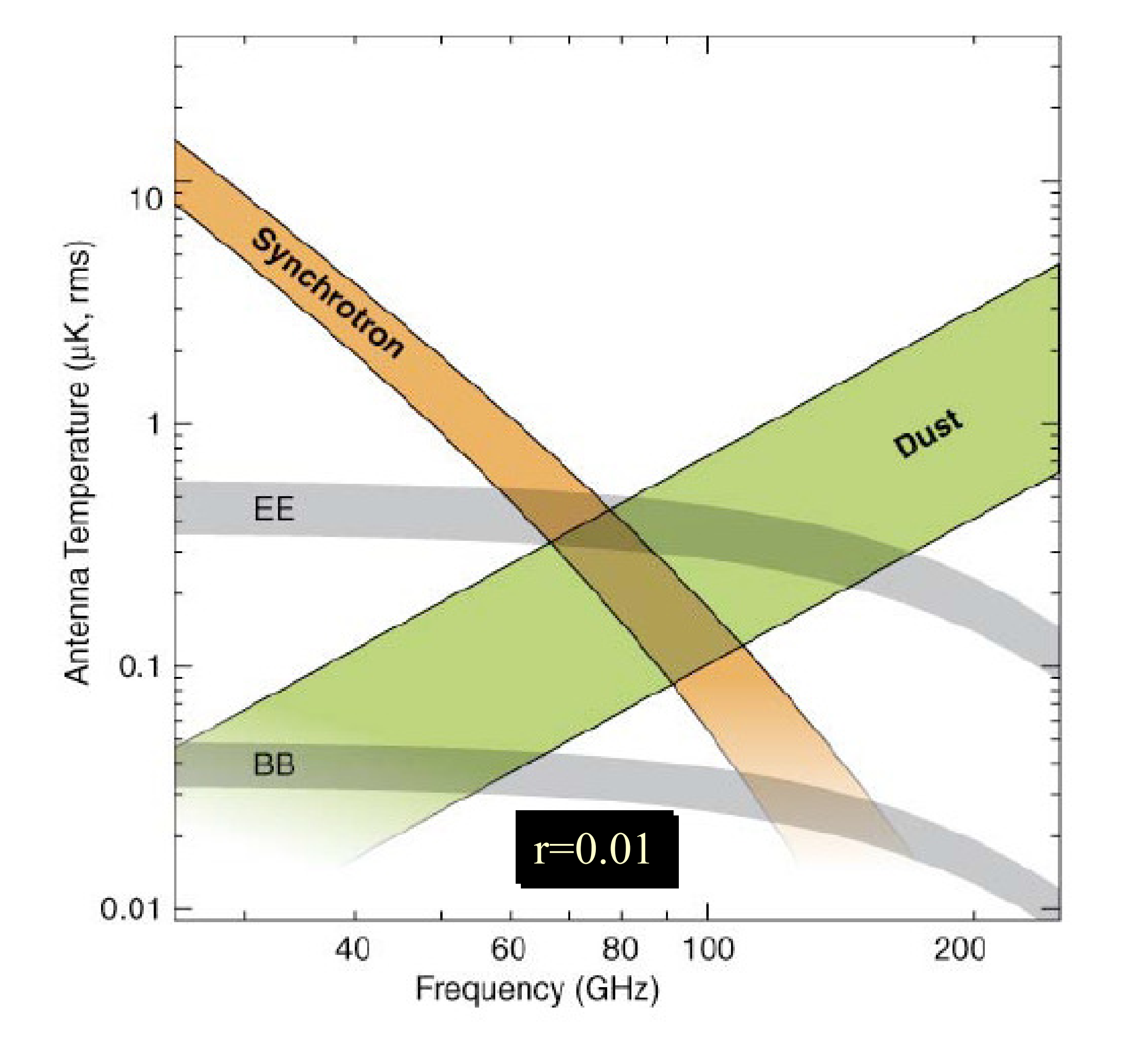
42 GHz
$\Delta\nu$ = 8 GHz
40 polarim.
N_tel= 1
T_sys= 30 K
FWHM= 1 deg
3 yr eff. integration

0.5μK/beam
Over 5000 sq deg



r=0.05 detection goal

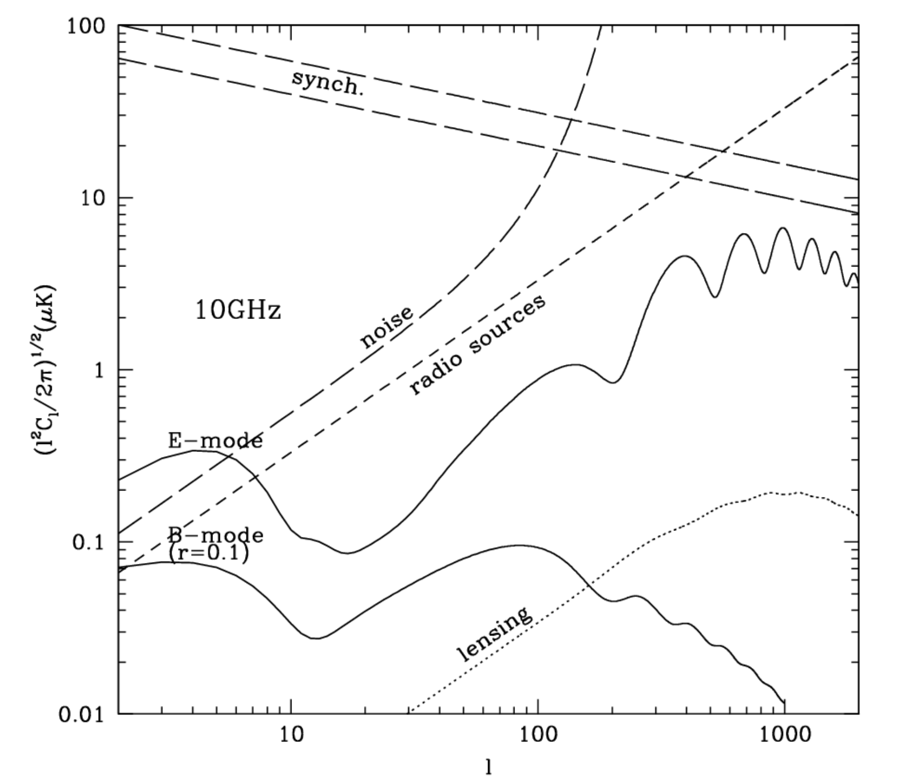
CMB foregrounds in the polarized microwave sky

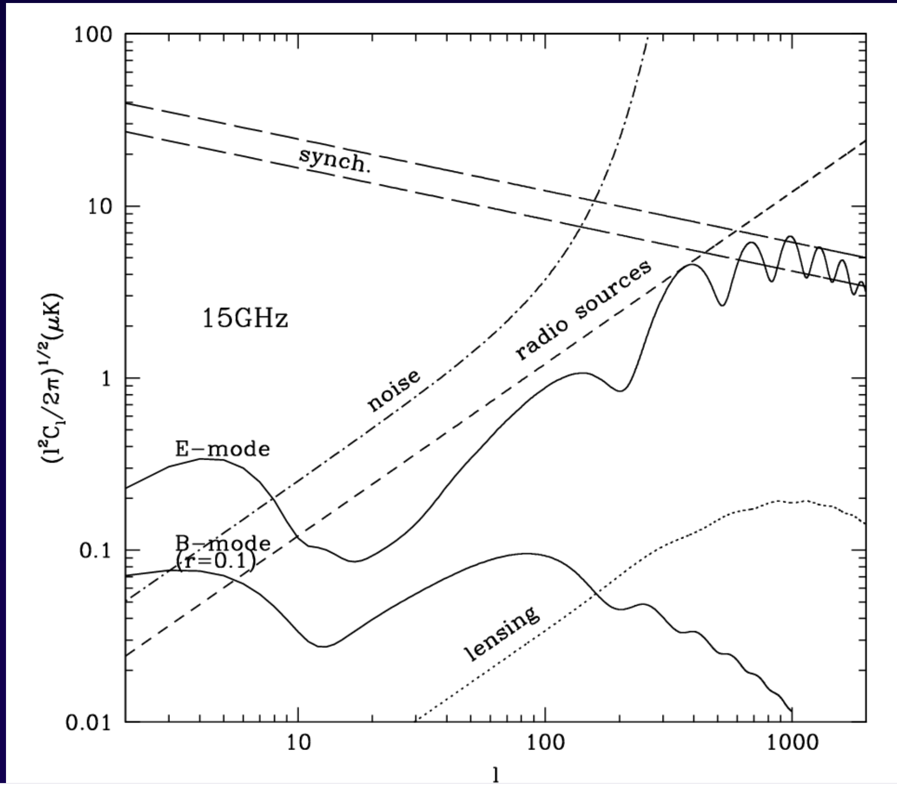


- A detailed study of the polarized large-scale emission from our Galaxy in the microwave band is needed.
- Extrapolations from low frequency surveys or high frequency studies (dust emission) show that the polarized CMB signal is never dominant.

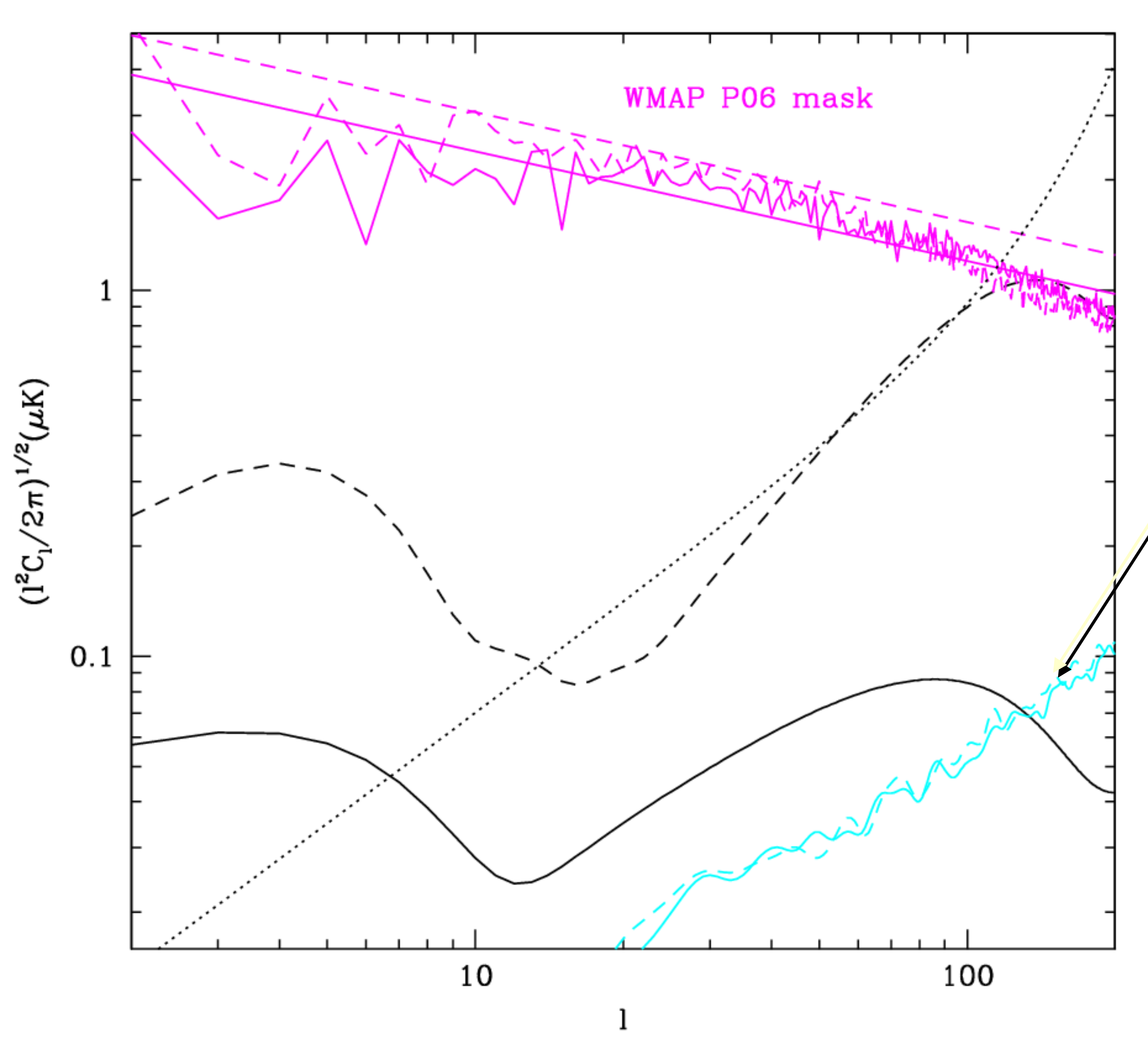
1. Correction of synchrotron emission at 30GHz

- We will obtain 4 frequency maps of the synchrotron polarization between 10 and 20 GHz, each with a sensitivity around 1-2μK per beam.
- Synchrotron frequency dependence scales approx. as ν^{-3}
- This will allow to predict the synchrotron contribution at 30 GHz with a precision better than 0.02 μK per sq. deg.





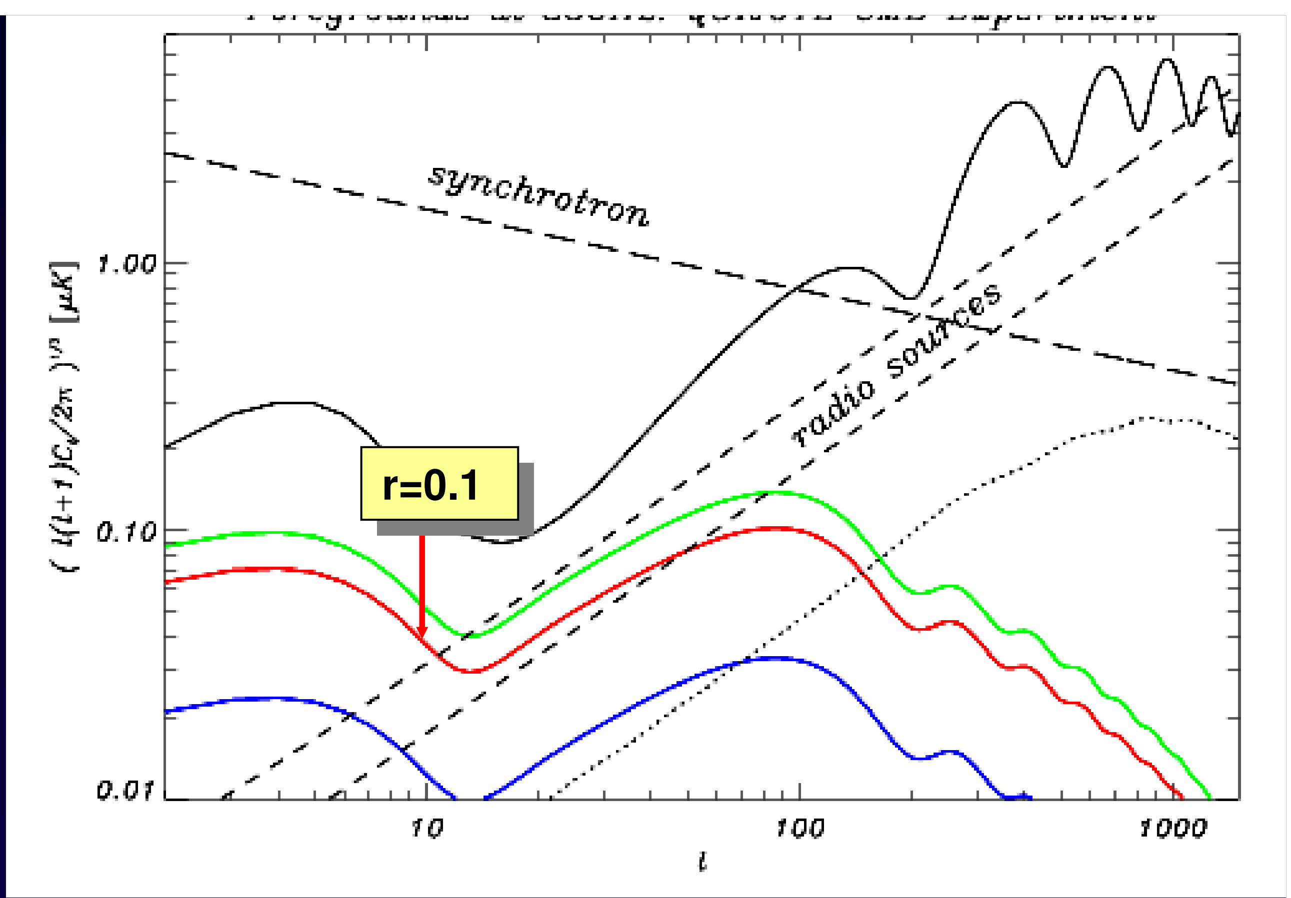
Correction of synchrotron emission at 30GHz



Synchrotron residual, assuming a pure power-law dependence in the 10-30 GHz frequency range, and sensitiv. 2μK per beam in the lower-frequency channels, performing a pixel-by-pixel correction.

2. Extragalactic Radiosource Foreground

contamination at 30 GHz as compared with BB modes.



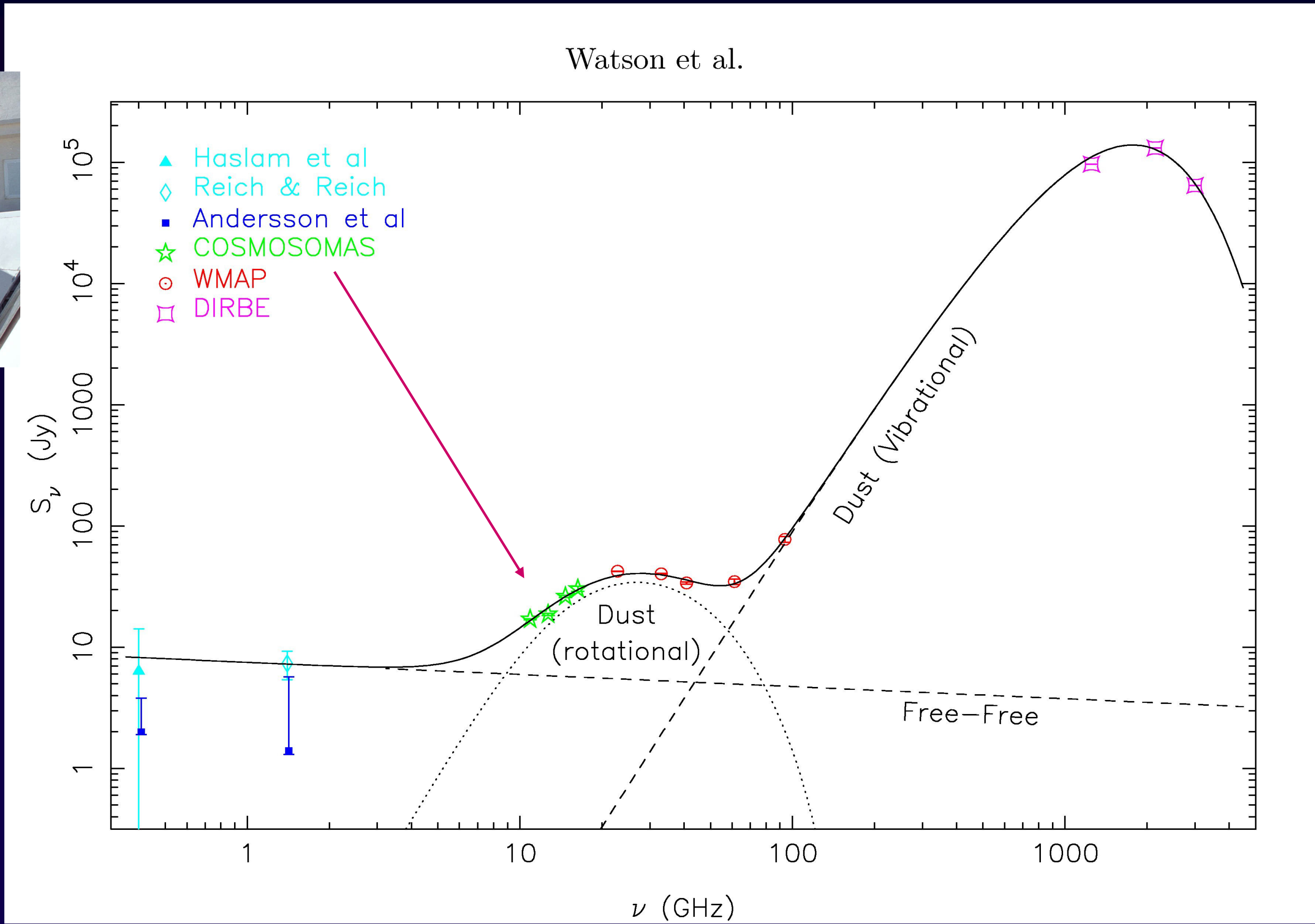
Extragalactic radio sources contribution (short dashed line) for the case of subtracting from the maps the polarization of sources down to 1 Jy in total intensity (upper line) and 300 mJy (lower line) Tucci et al.

2. Extragalactic Radiosource correction

A dedicated instrument at 30 GHz: VSA subtractor converted to a polarimeter.

We estimate less than 500 sources with flux> 300 mJy Will have to be measured and corrected in the maps

3. Anomalous microwave emission

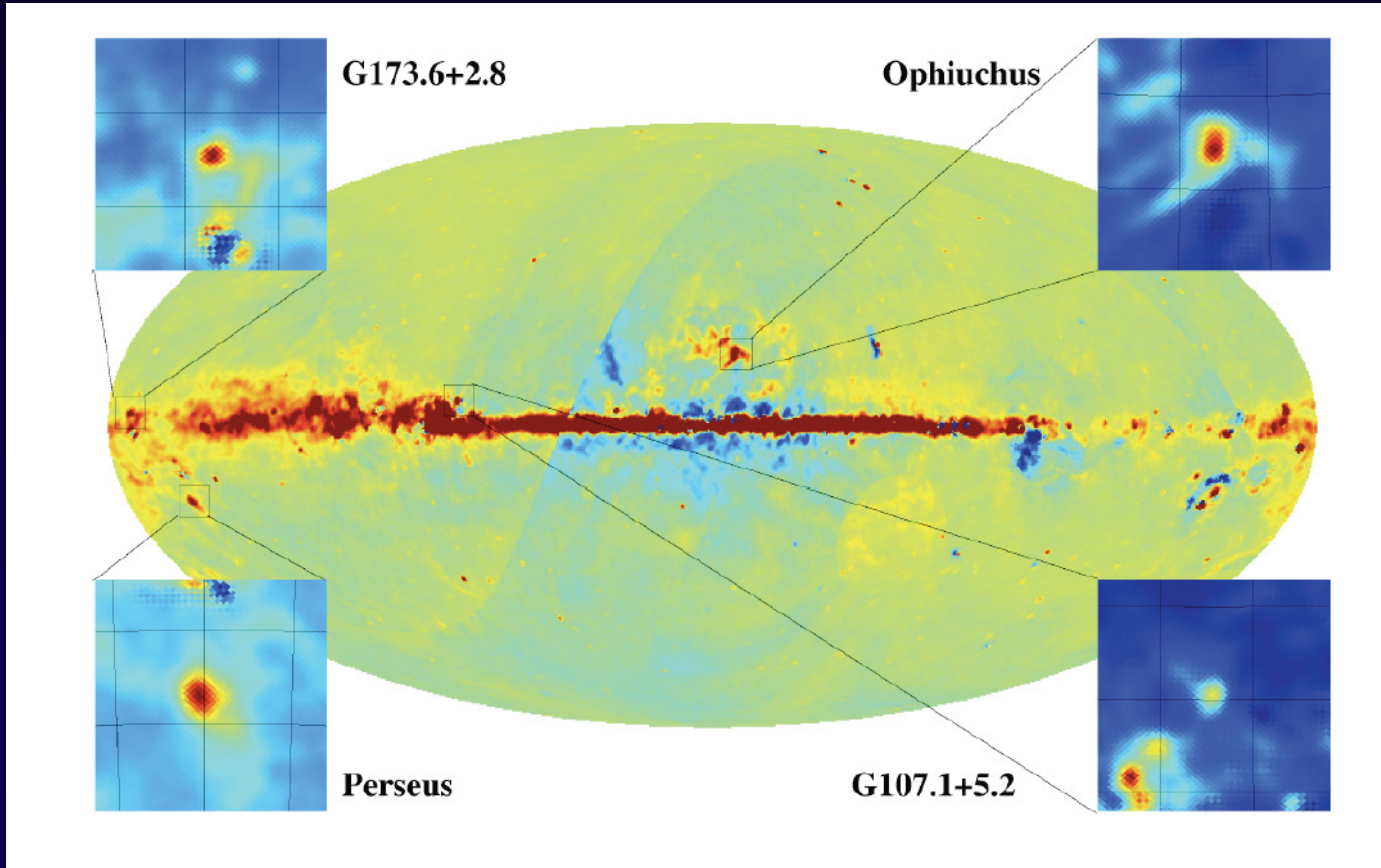


A clear example: The Perseus Molecular Complex

Watson, Rebolo, Rubiño et al. 2005, ApJ 624 L89

Anomalous Microwave emission:

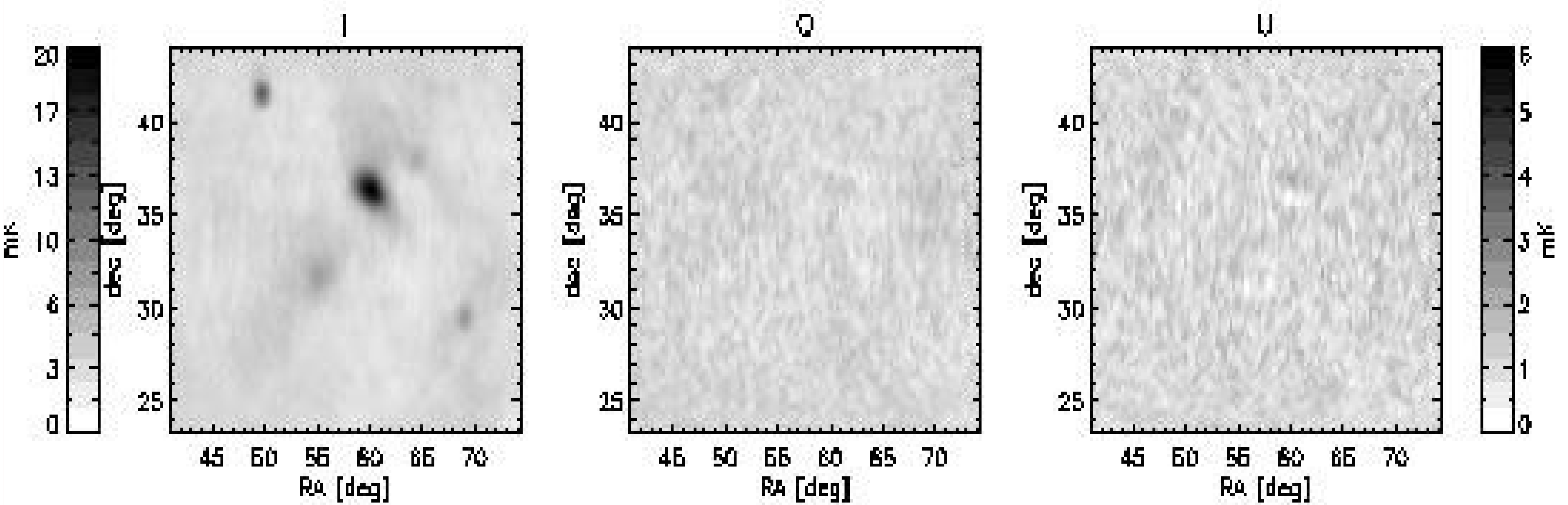
The Planck collaboration XX (2011)



Anomalous microwave emission: Is polarization a problem?

Polarization observations of anomalous microwave
emission at 11 GHz in the Perseus molecular complex

Battistelli, Rebolo, Rubiño et al. 2006 ApJ



Q: difference between the radiation intensity collected by COSMOSOMAS in the 0º plane (North-South) and the 90º one. **Q= - 0.2** ±1.0 % (95% c.l.)

U : difference between the orientation –45º and +45º. U=-3.4±2% (95% c.l.)

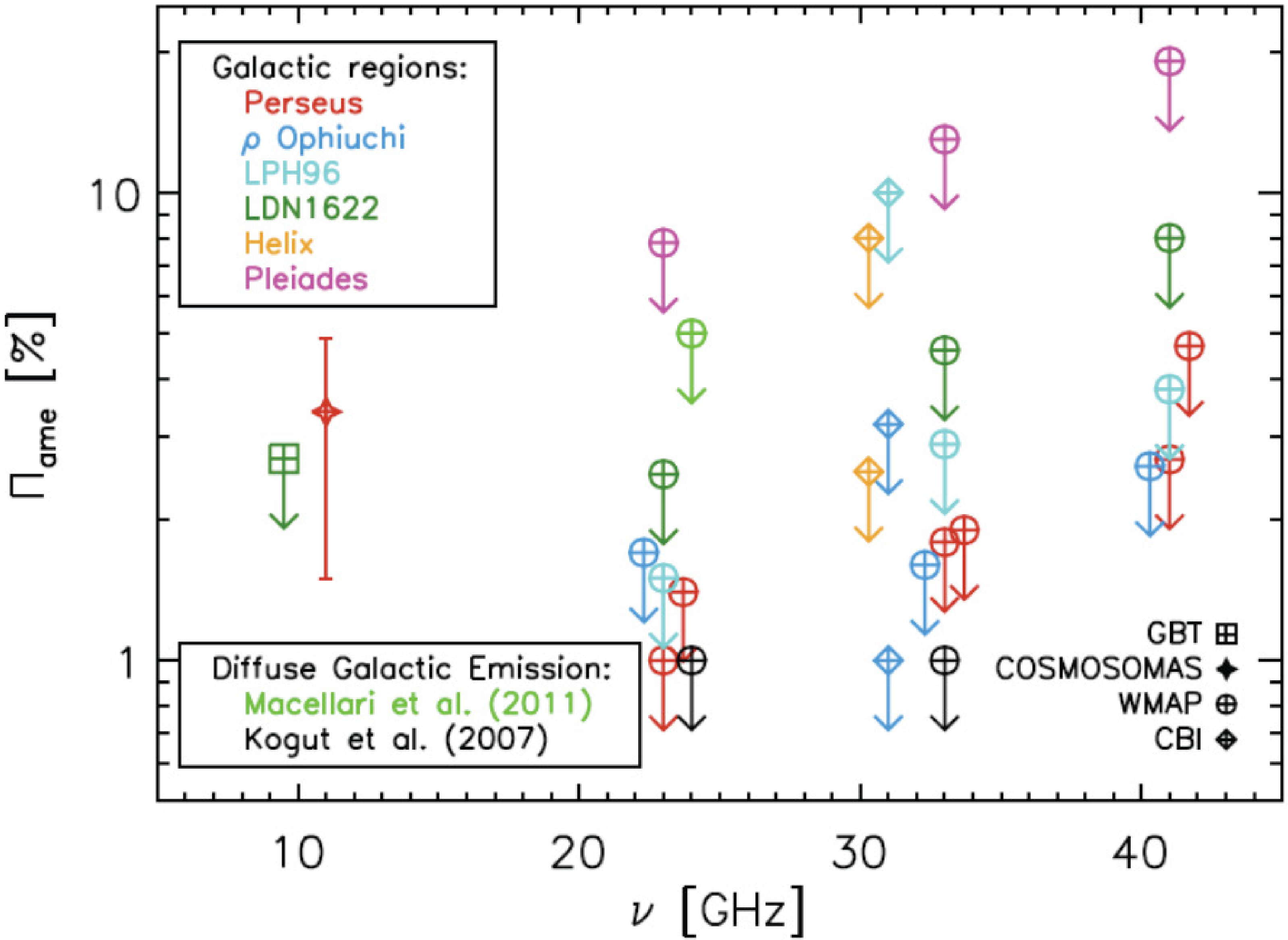
Overall polarization parameter Π=3.4 ± 2%.

WMAP-7yr (Perseus) $\Pi <$ 1% at 22 GHz, (López-Caraballo et al. 2011 ApJ)

Possible carrier for the emission?

Carbon based molecules with permanent electric dipole

Current status of AME polarization measurements



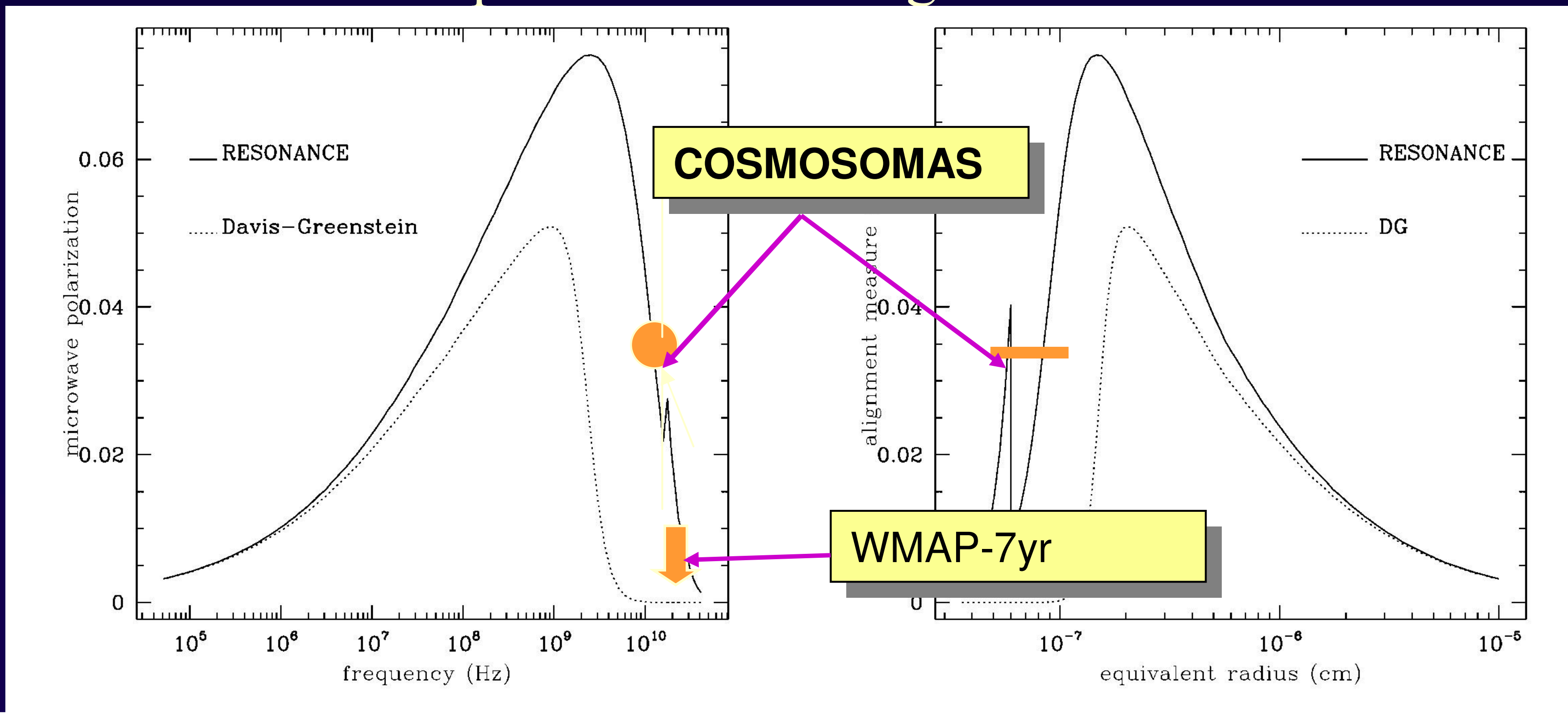
Rubino-Martin et al. (2012, in prep).

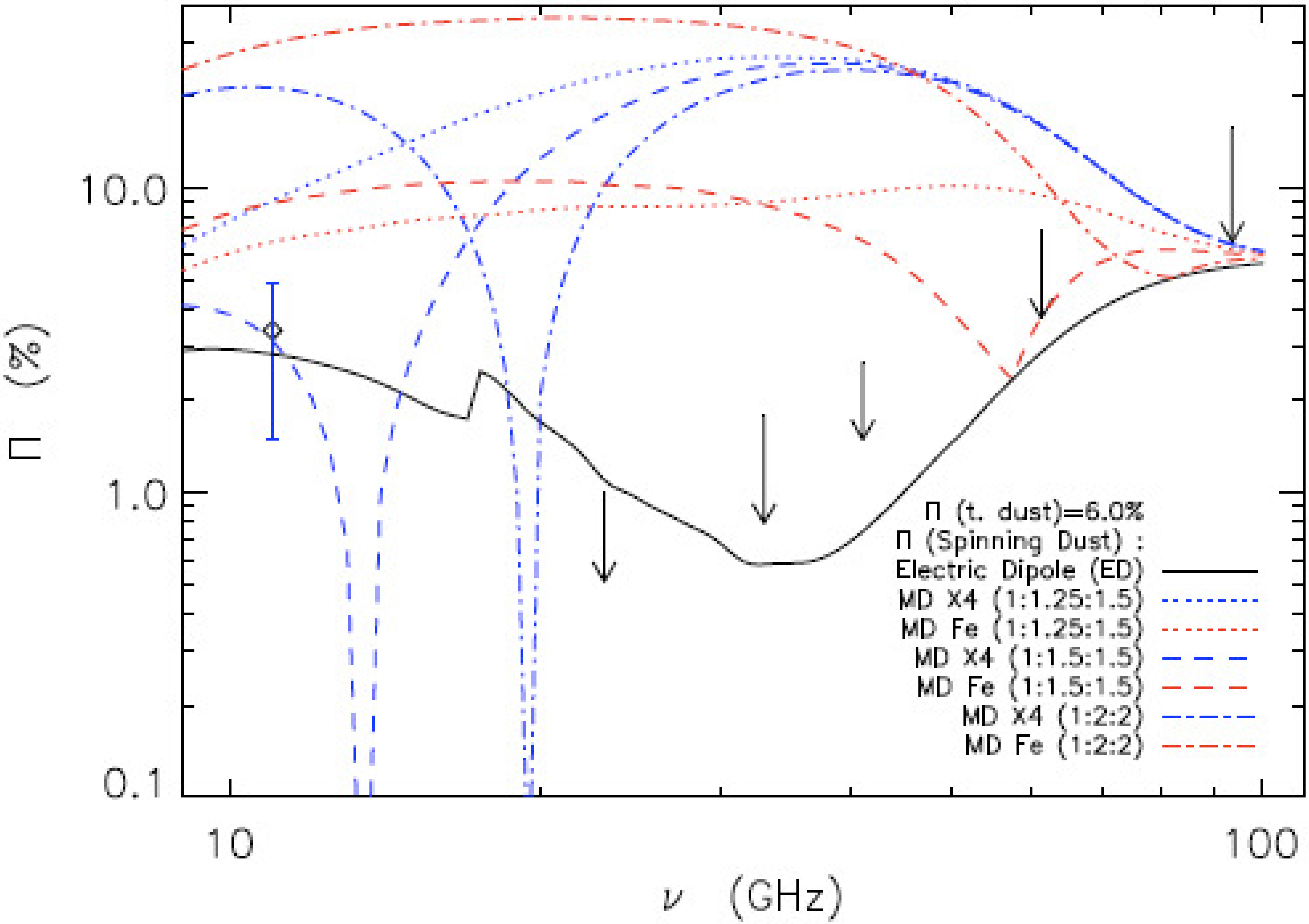
Polarization of electric dipole radiation

Lazarian and Draine 2000 ApJ

Are the molecules aligned and their emission polarized?

The energy level splitting arising from grain rotation ensures maximum efficiency of paramagnetic dissipation : time dependent magnetization, energy dissipation and torque causing the molecules to rotate with the axis parallel to the magnetic field

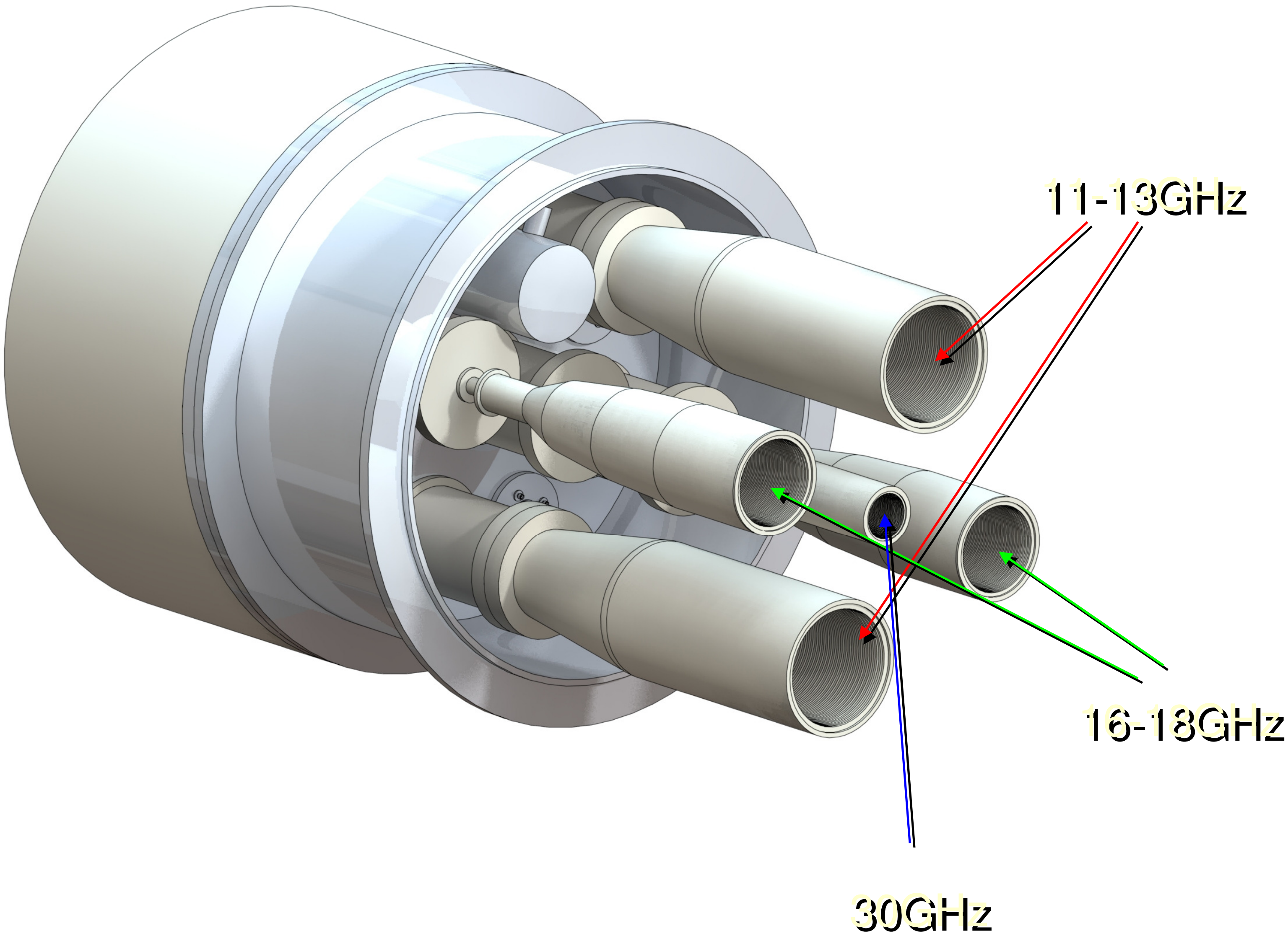




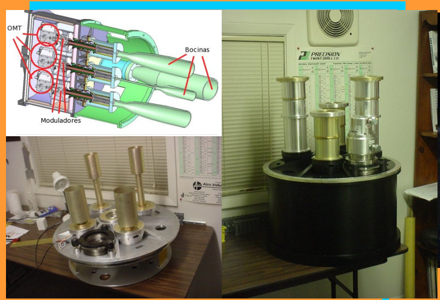
López Caraballo et al. 2010 ApJ

Status of the QUIJOTE Instruments

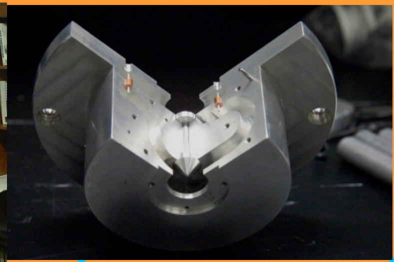
QUIJOTE First instrument



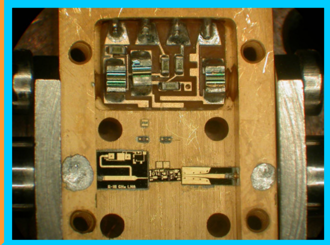
QUIJOTE INSTRUMENTATION



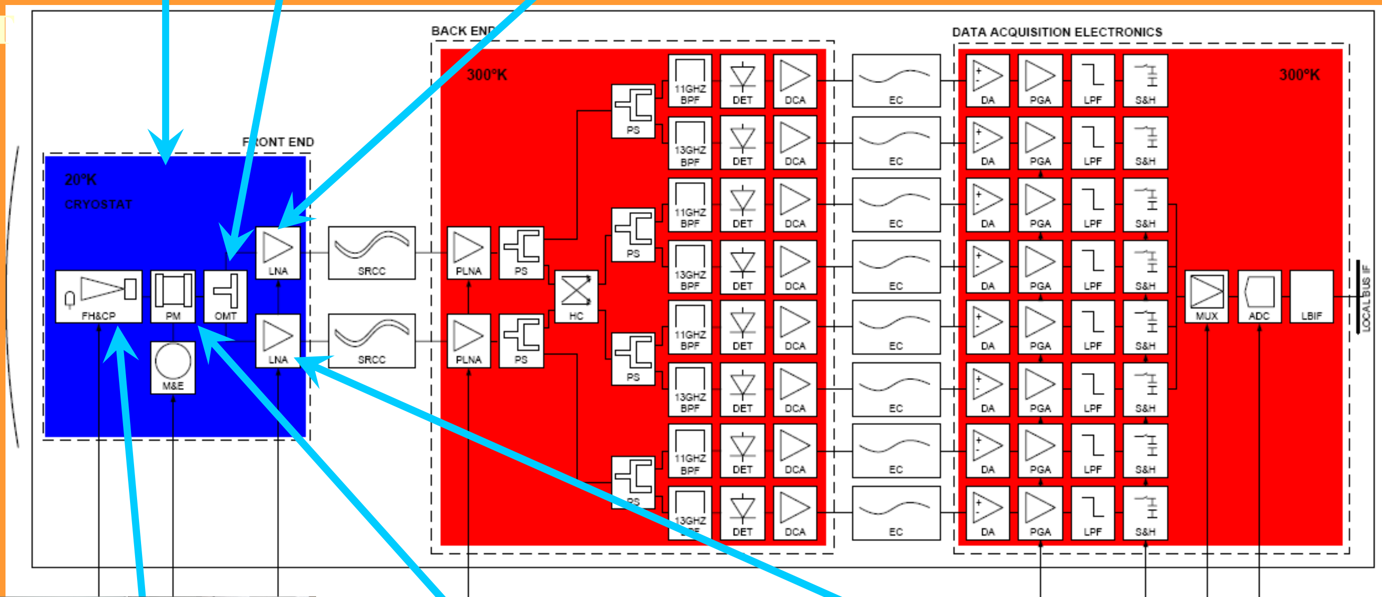
QUIJOTE CRYOSTAT



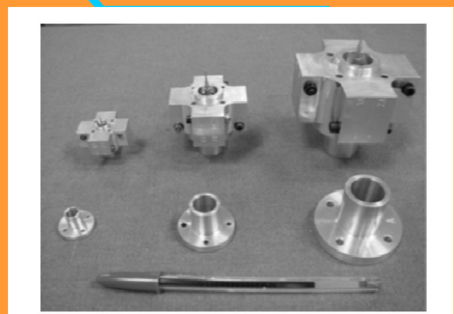
OMT



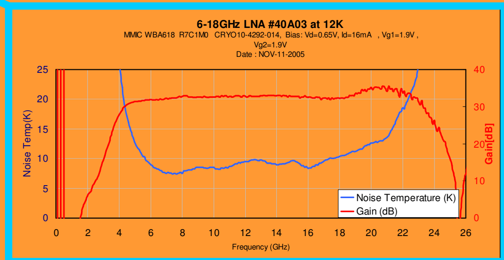
LNAs 6-18GHz



HORN

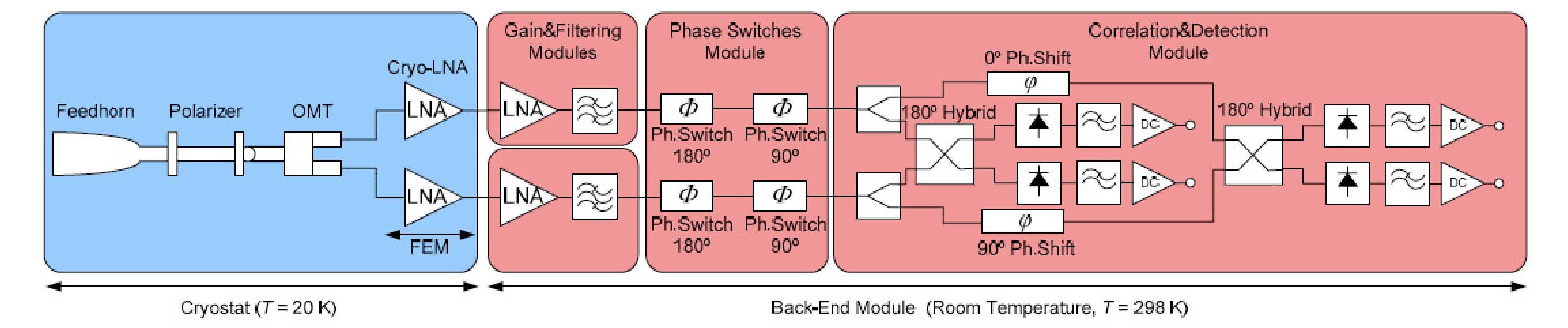


POLAR MODULATOR



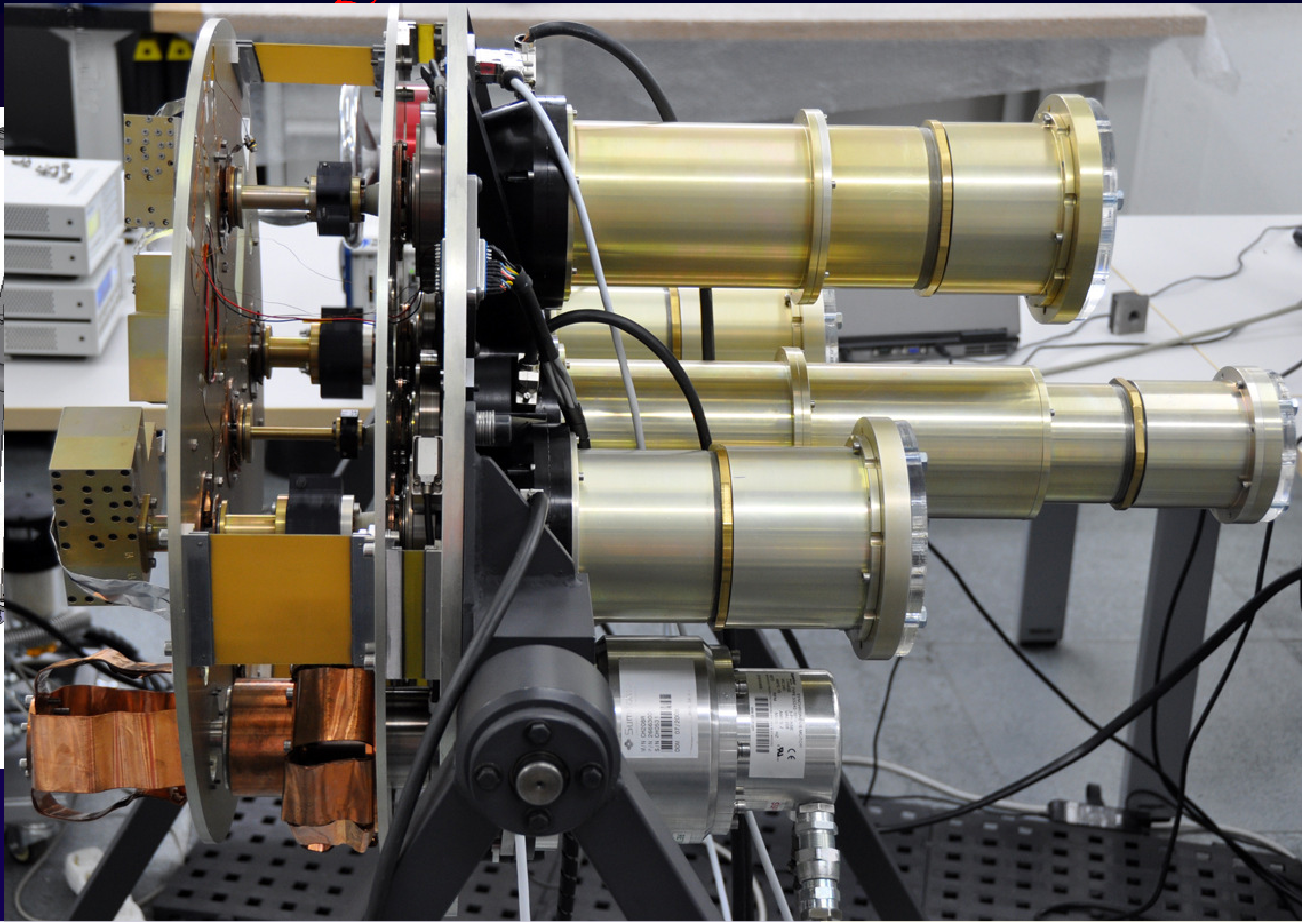
LOW NOISE AMPS

Thirty-GHz Instrument (TGI)



• MFI not appropriate for the long-term operations required for TGI.
• New design: We have modified the receiver configuration by replacing the rotating polar modulator with a fixed polarizer
• It includes a fixed polarizer and 90 and 180 phase switches to generate four polarisation states to minimize the different systematics in the receiver.

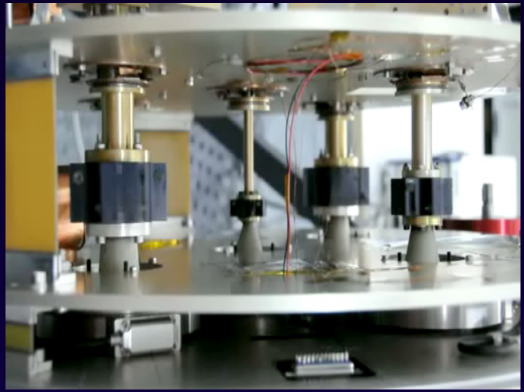
QUIJOTE First instrument



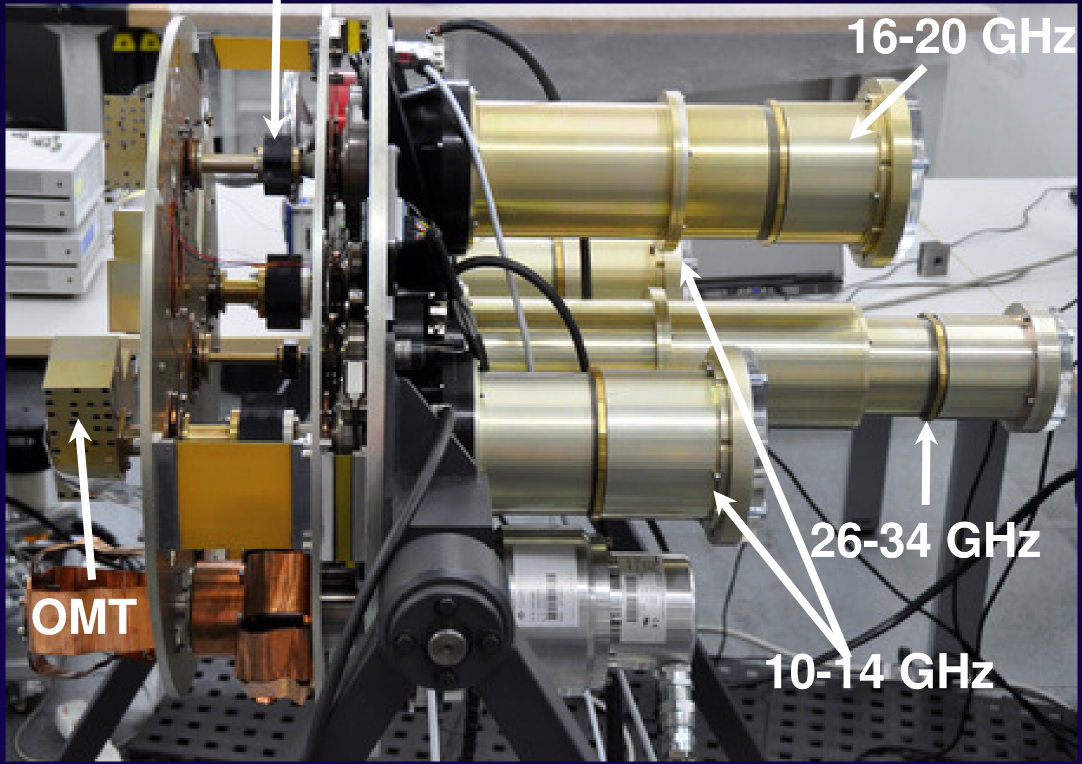
QUIJOTE first instrument

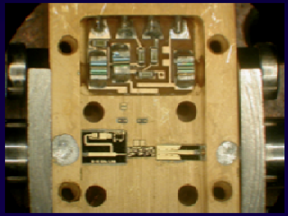
- 2 horns providing 8 channels at 11 and 13 GHz
- 2 horns providing 8 channels at 17 and 19 GHz
- 1 horn providing 2 channels at 30 GHz

Spinning polar modulators



Polar Modulators



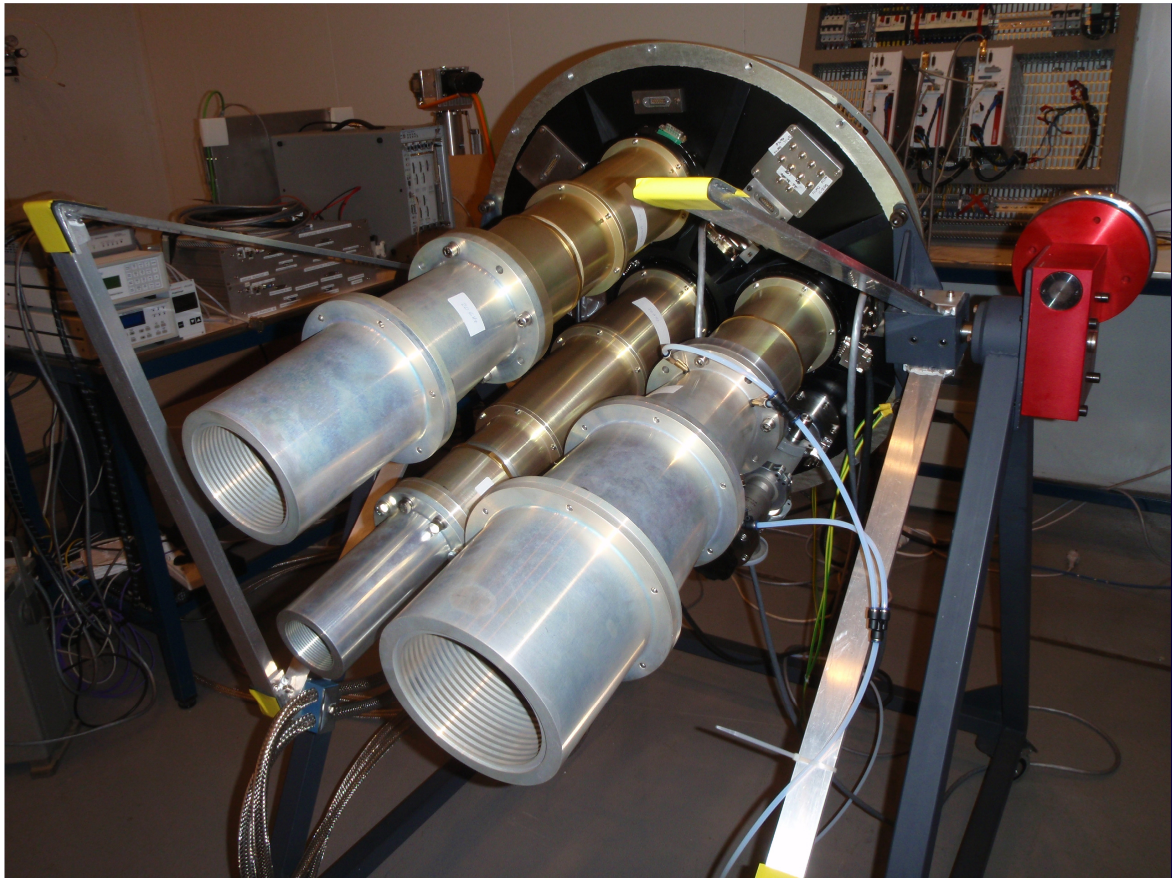


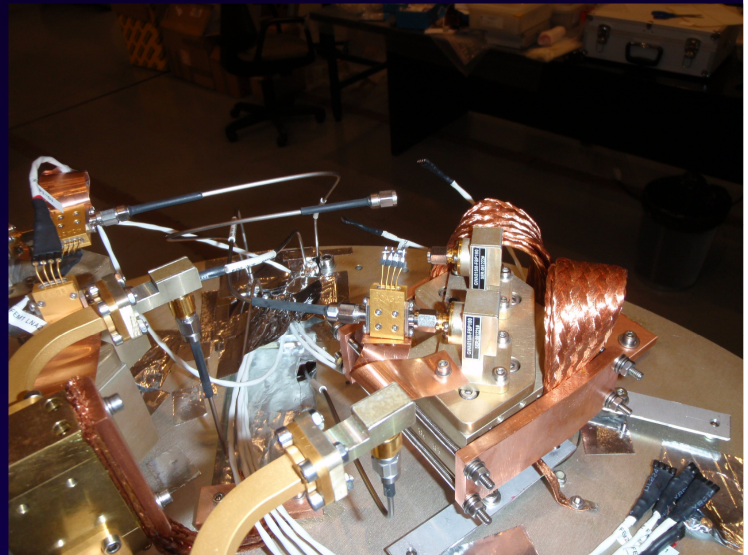
LNA

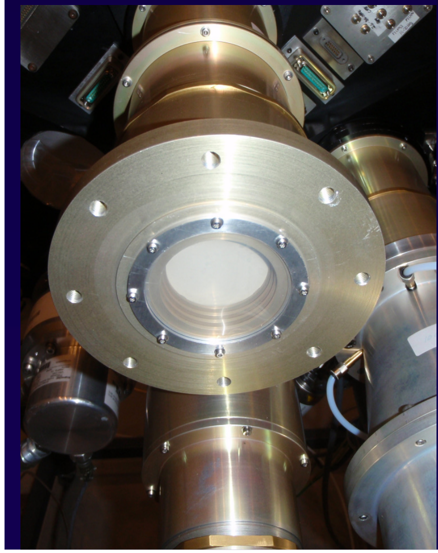
OMT and motor

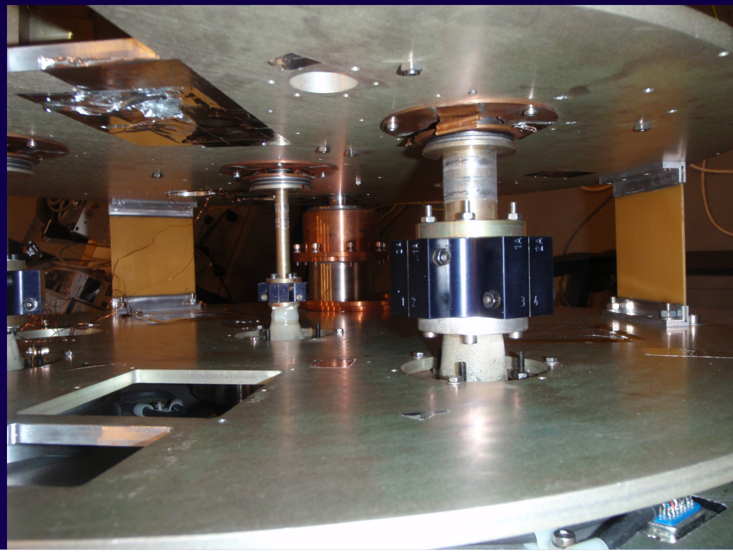
Horns

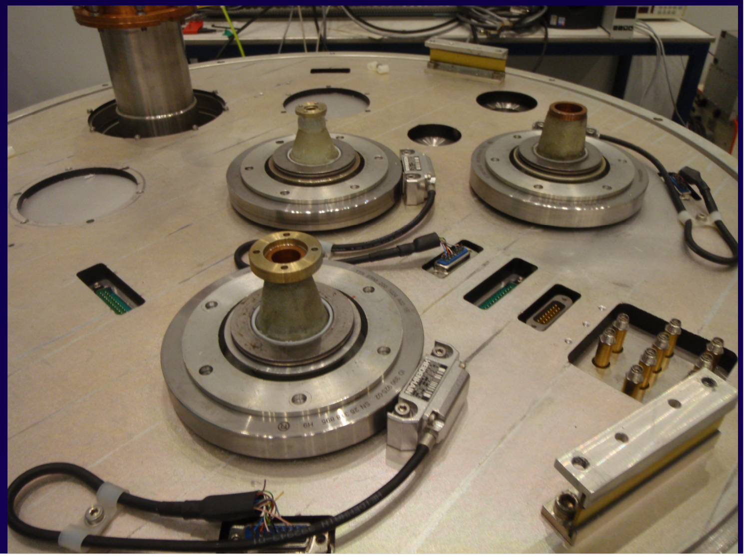
QUIJOTE MFI.
Final integration





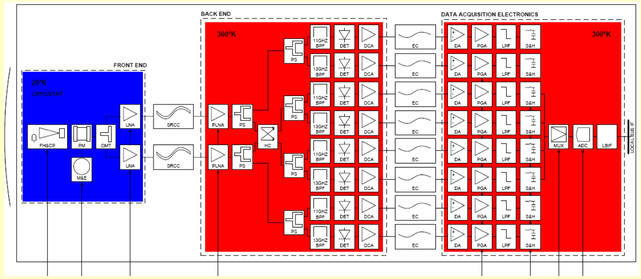


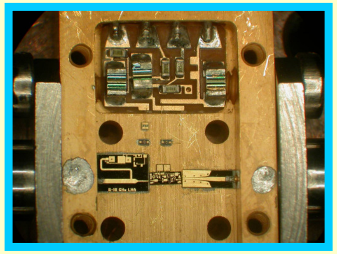




QUIJOTE MFI: FEMs and BEMs

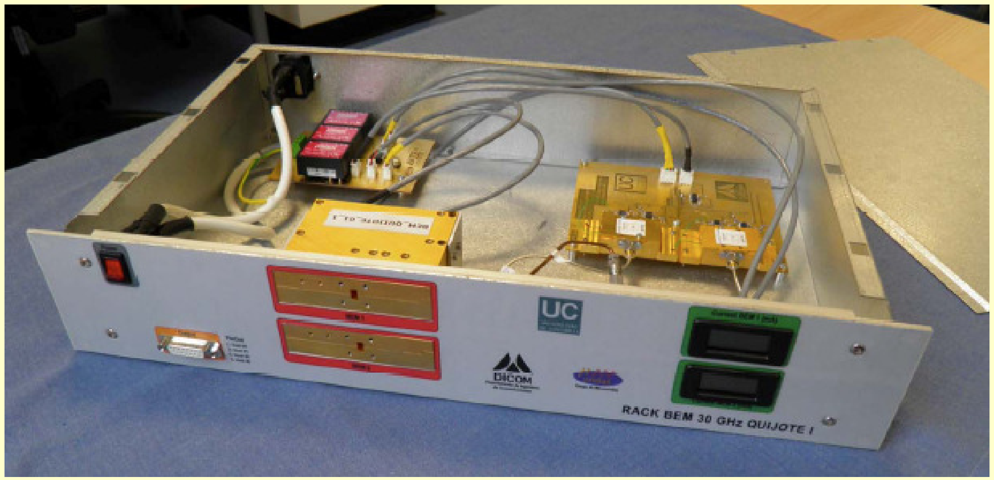
* FEMs: in AIV phase.





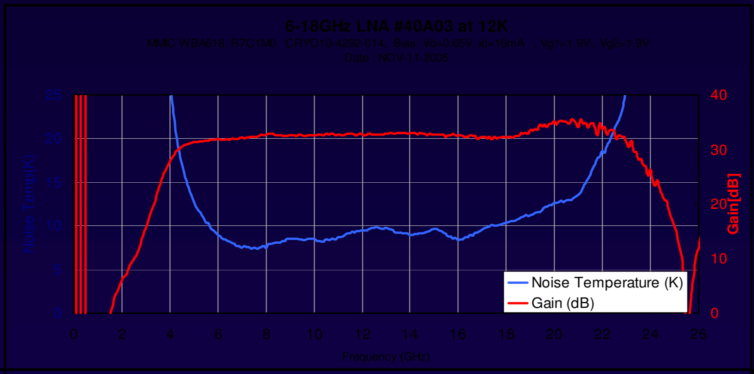
Band / polarimeter	Avg, Noise temp, K
10-14GHz / 1	7K
10-14GHz / 1	10K
10-14GHz / 2	9K
10-14GHz / 2	10K
16-20GHz / 1	10K
16-20GHz / 1	12K
16-20GHz / 2	17K
16-20GHz / 2	21K
25-35GHz	18K

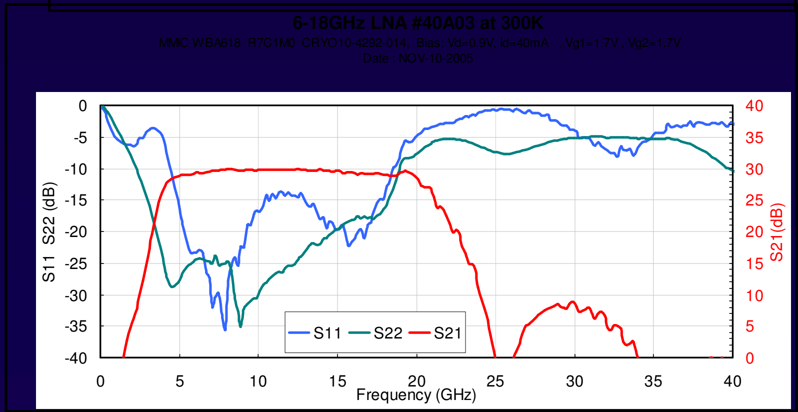
* BEMs: in AIV phase.

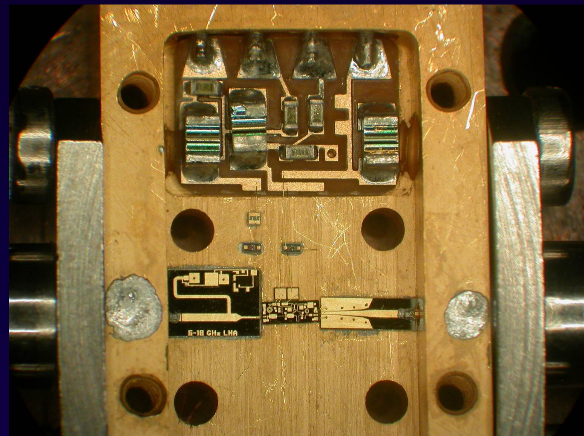


MMIC 6-18GHz LNA (Caltech)

(S. Weinreb)



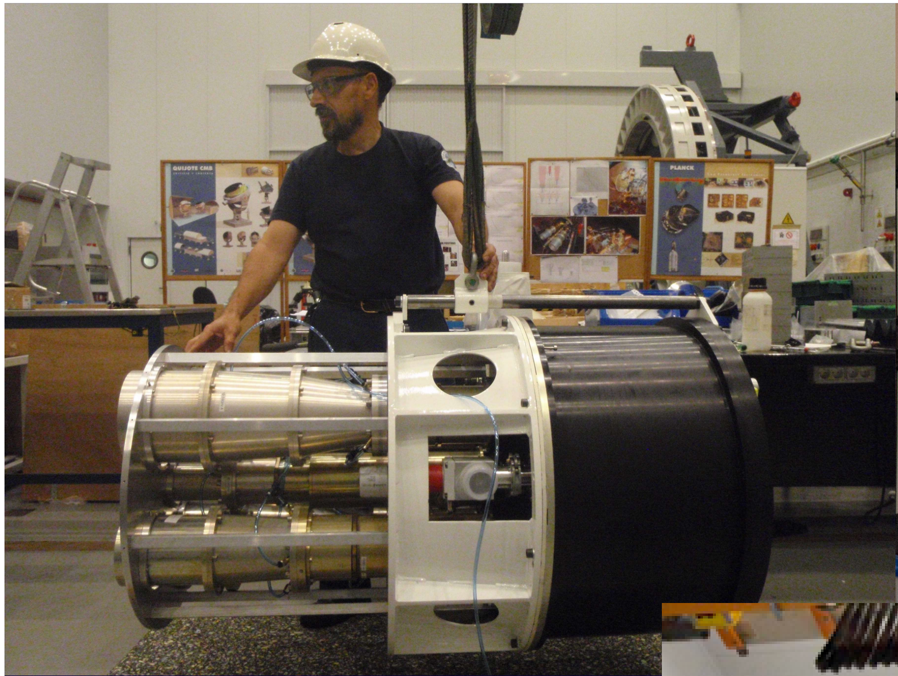


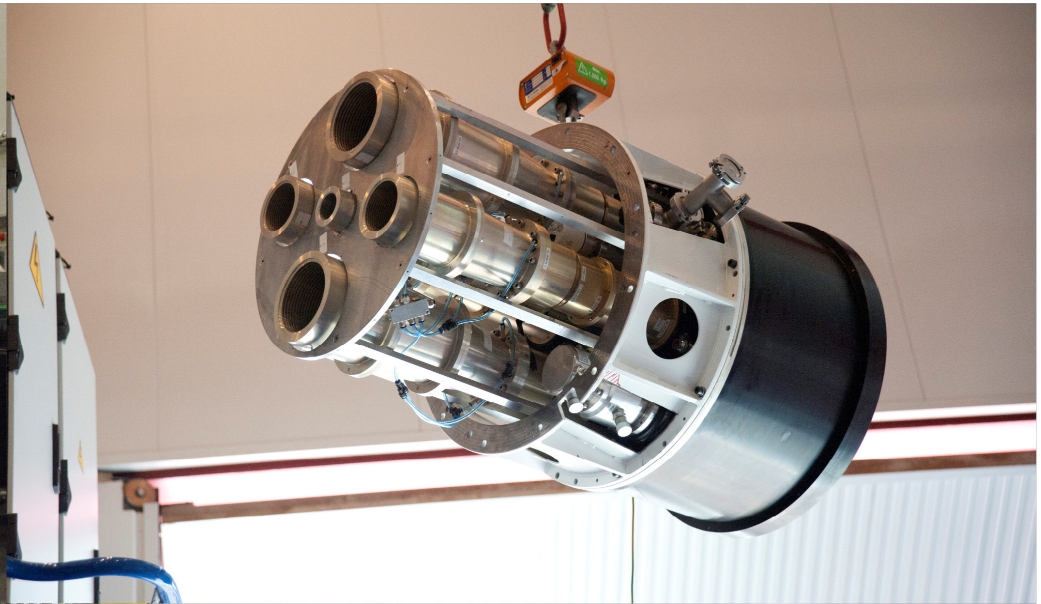


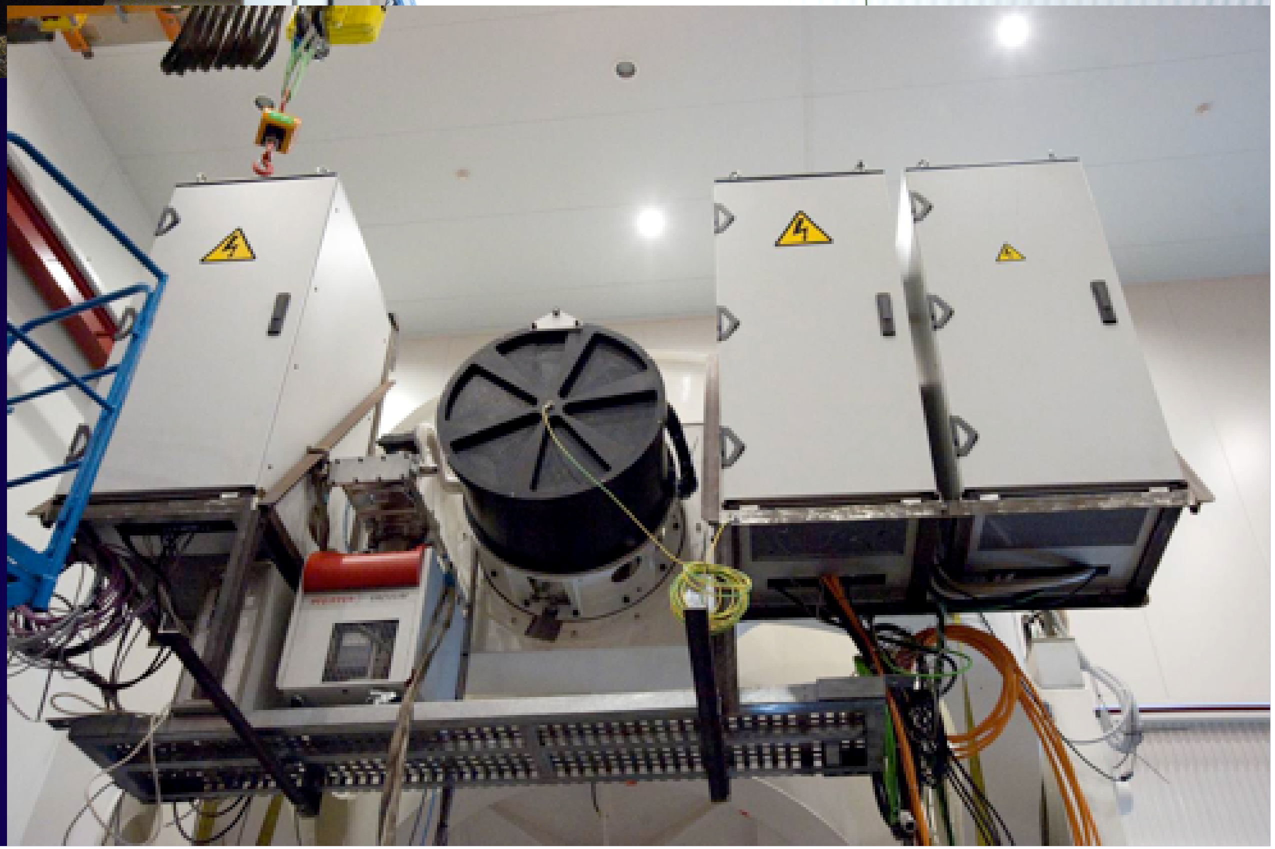
Gain = approx. 30dB

NT ~ 10K

For the second instrument (31 polarimeters at 30GHz) , we will use LNAs built at Cantabria Univ. (E. Artal) based on MMICs from the Fraunhofer Inst.







Integration tests of the MFI and QT1 at the AIV room (February-March 2012)

Concluding remarks

- This decade CMB polarization experiments from ground and balloons will provide unique information about the polarization of foregrounds improving current constraints on the tensor modes by a factor 4-5.
- QUIJOTE-CMB will explore the polarization of the synchrotron and anomalous emission from our Galaxy at low frequencies (10-40 GHz) providing very valuable information for present (Planck, 30-800 GHz) and future space B-mode experiments (CORE)
- QUIJOTE / Planck shall be able to provide a good control on systematics and detect a B-mode signal due to primordial gravitational waves if r~0.05

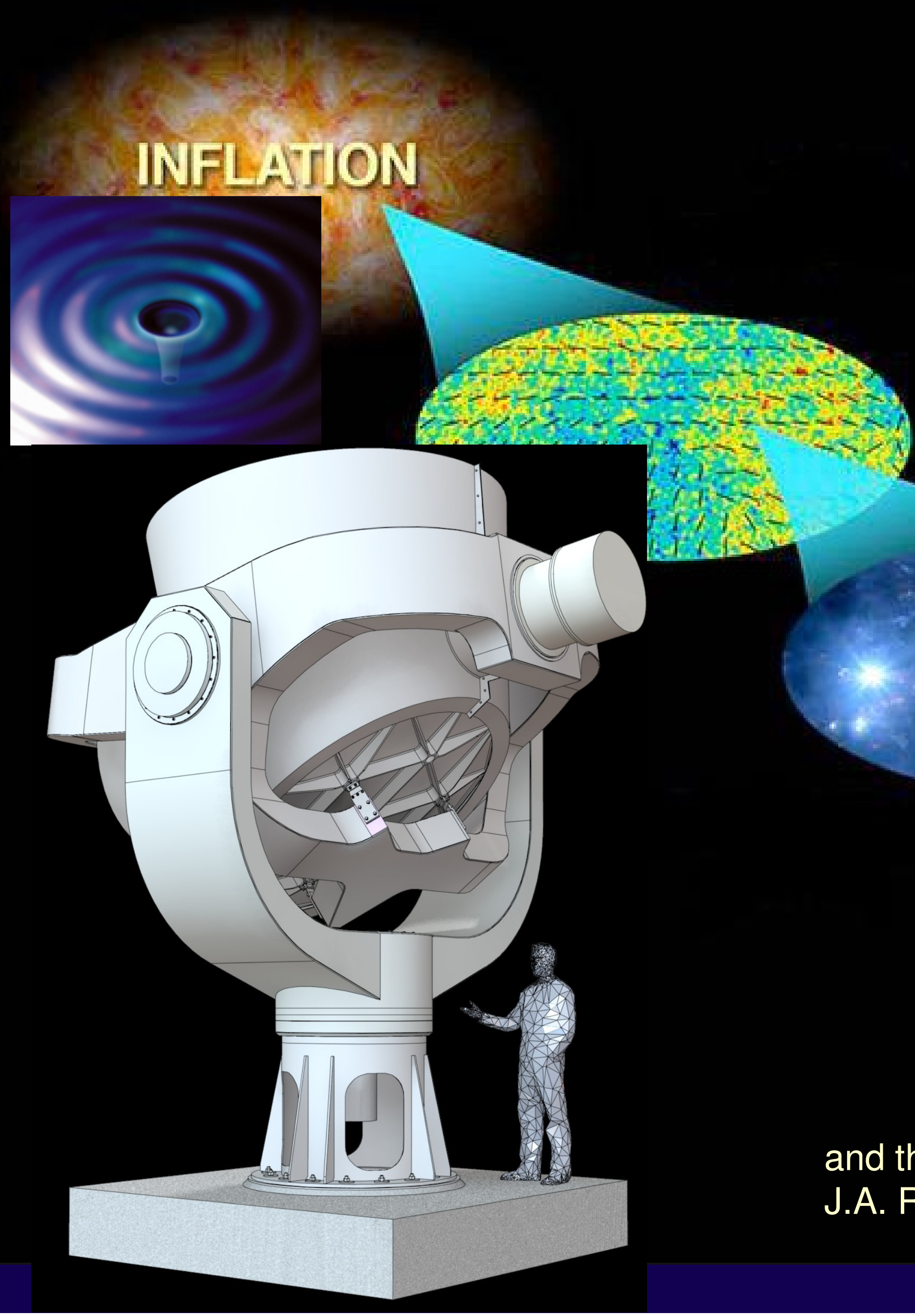
Dalí 1945

EL INGENIOSO
HIDALGO DON QVI-
XOTE DE LA MANCHA.
Compuesto por Miguel de Ceruantes Saauedra.
DIRIGIDO AL DVQVE DE BEIAR,
Marques de Gibraleon, Conde de Benalcaçar, y Bañares, Vizconde de la Puebla de Alcozer, Señor de las villas de Capilla, Curiel, y Burgillos.

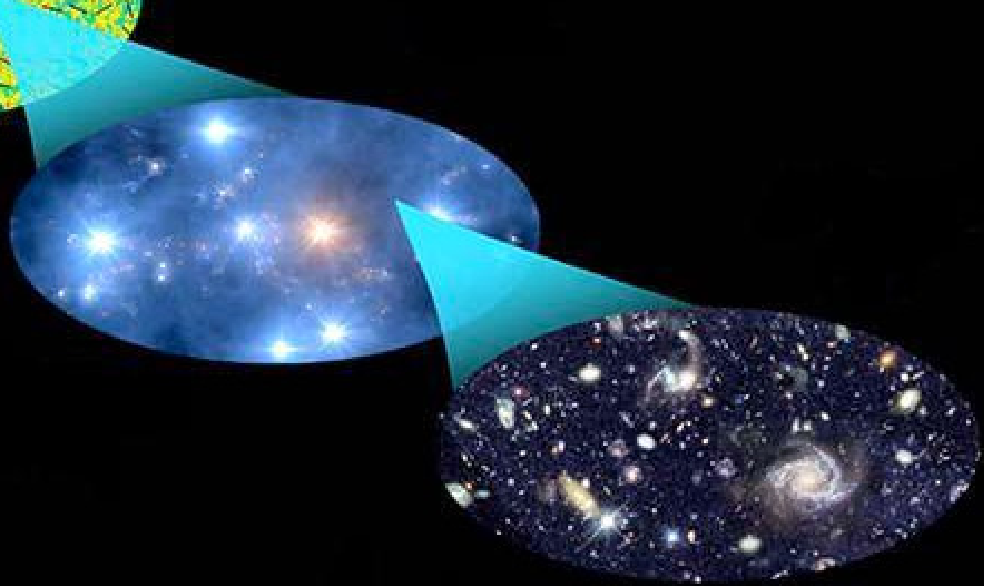
Año 1608.

Con priuilegio de Castilla, Aragon, y Portugal.
EN MADRID, Por Iuan de la Cuesta.
Vendese en casa de Francisco de Robles, librero del Rey nro señor.

We are riding…



Thanks for your attention!



and thanks to the QUIJOTE team, in particular to J.A. Rubiño for providing material for this talk