Observational Constraints on the Polarization of AME
(and prospects for QUIJOTE-CMB experiment)

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Outline

- Polarization of the Anomalous Microwave Emission (PAME).
- Current Measurements:

  Galactic Regions: 6 regions.
  Dust Clouds: Perseus, ρ Ophiuchi, LDN1622, Pleiades
  HII : Helix and LPH96

  Diffuse Galactic Emission: 2 works using WMAP3 and WMAP5
- QUIJOTE-CMB experiment.
- Implication for future B-modes experiments.

PAME: EDE Models

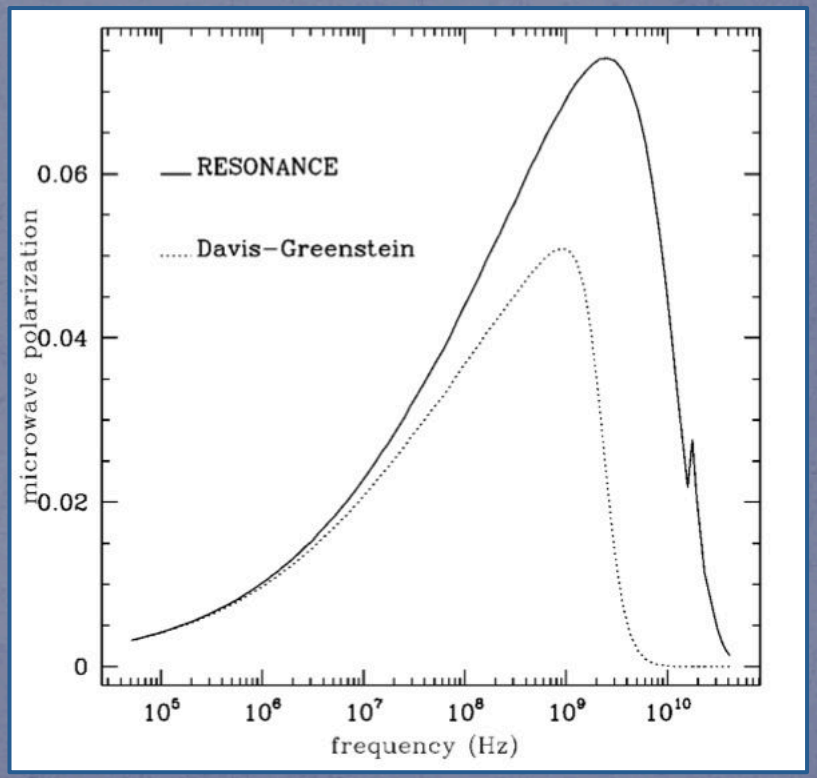
Electric Dipole → **Intensity**

↓

Polarization

- It is the most favoured physical process to explain the AME.
- It has been detected in individual regions and at large-scales.

Lazarian and Draine 2000: Spinning dust and resonance relaxation.



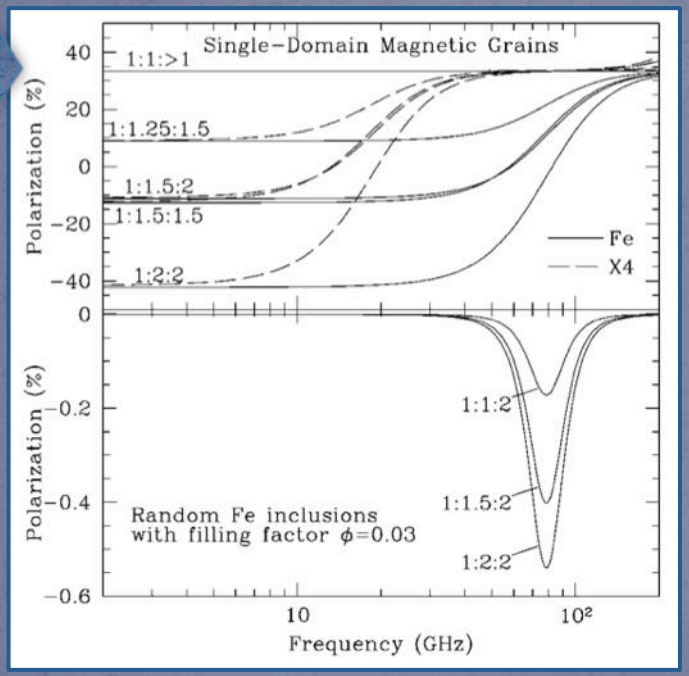
- Low levels of polarization:
  - 6%-7% at 2-3GHz.
  - 4%-5% at 10 GHz.
  - < 1% at 20 GHz.

PAME: MDE Models

Magnetic Dipole Emission

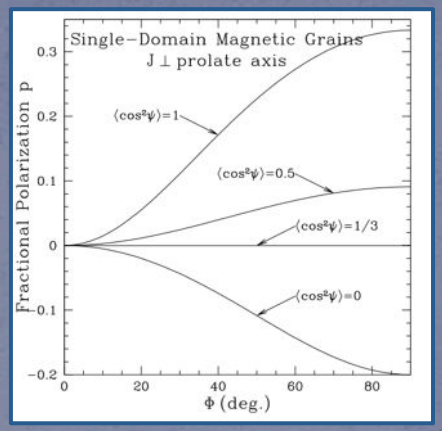
(remember Hensley`s talk)

Draine and Lazarian 1999



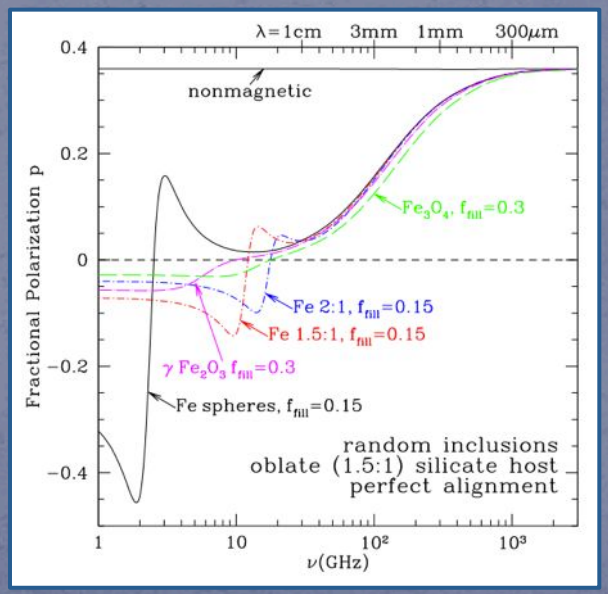
Strong polarization levels in 20-30GHz

At 33 GHz (approx.): 10% - 30 %
In perfectly-aligned.



DL99 models correspond to maximal values

Draine and Hensley 2012



New MDE family with Mag inclusions.

Low polarization levels at 10-30 GHz.

At 33 GHz (approx.): ≤ 10 %
Depending on the Mg. Inclusions.

PAME: Observations

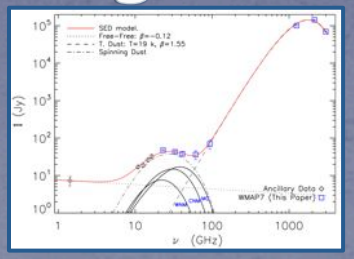
Current observational measurements

Name	Experiment	Resolution	Π(9–11 GHz) [%]	Π(22 GHz) [%]	Π(30–33 GHz) [%]	Π(40 GHz) [%]	References
			Galactic AME regions				
G159.6-18.5	COSMOSOMAS	1°	$3.4^{+1.5}_{-1.9}$				Battistelli et al. 2006
”	WMAP7	1°		< 1.01	< 1.79	< 2.69	López-Caraballo et al. 2011
”	WMAP7	1°		< 1.4	< 1.9	< 4.7	Dickinson et al. 2011
LPH96	CBI	~ 9′			< 10		Dickinson et al. 2006
”	WMAP7	1°		< 1.5	< 2.9	< 3.8	This work
Helix	CBI	~ 9′			< 3.8		Casassus et al. 2007
ρ-Ophiucus	CBI	~ 9′			< 3.2		Casassus et al. 2008
”	WMAP7	1°		< 1.7	< 1.6	< 2.6	Dickinson et al. 2011
LDN1622	GBT	X	< 2.7				Mason et al. 2009
”	WMAP7	1°		< 2.5	< 4.6	< 8.0	This work
Pleiades	WMAP7	1°		< 10.6	< 28.5	< 82.2	This work
			Diffuse Galactic AME				
Full-Sky	WMAP3	1°		< 1	< 1	< 1	Kogut et al. 2007
Full-Sky	WMAP5	1°		< 5			Macellari et al. 2011

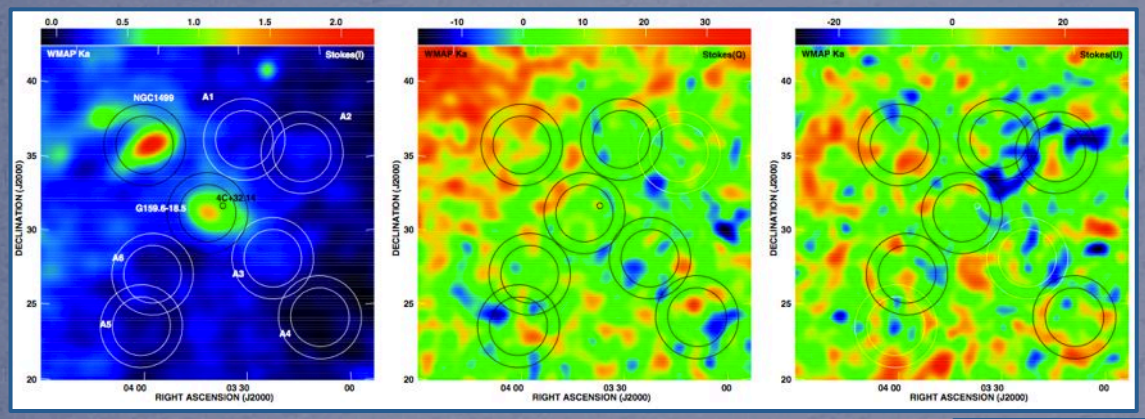
- From Rubiño-Martín et al. 2012 (in prep.) (**for AME Special Issue**)
- New upper limits for LDN1622, LPH96 and Pleiades (WMAP bands)

Galactic Regions: Perseus

G159.6-18.5
López-Caraballo et al. 2011



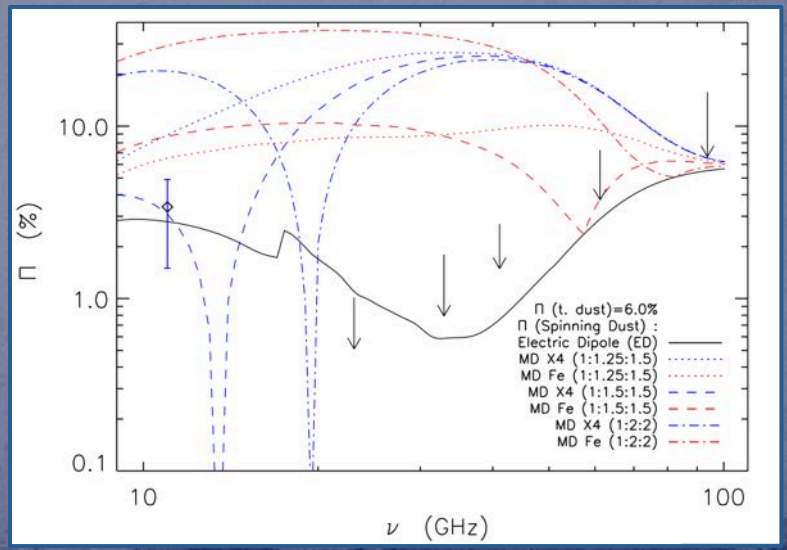
- Our results are compatible with Watson et al. 05.
- Recently studied by Planck.



- The ring analysis (direct integration) was applied.
- rad_0=2 deg.

Polarization:

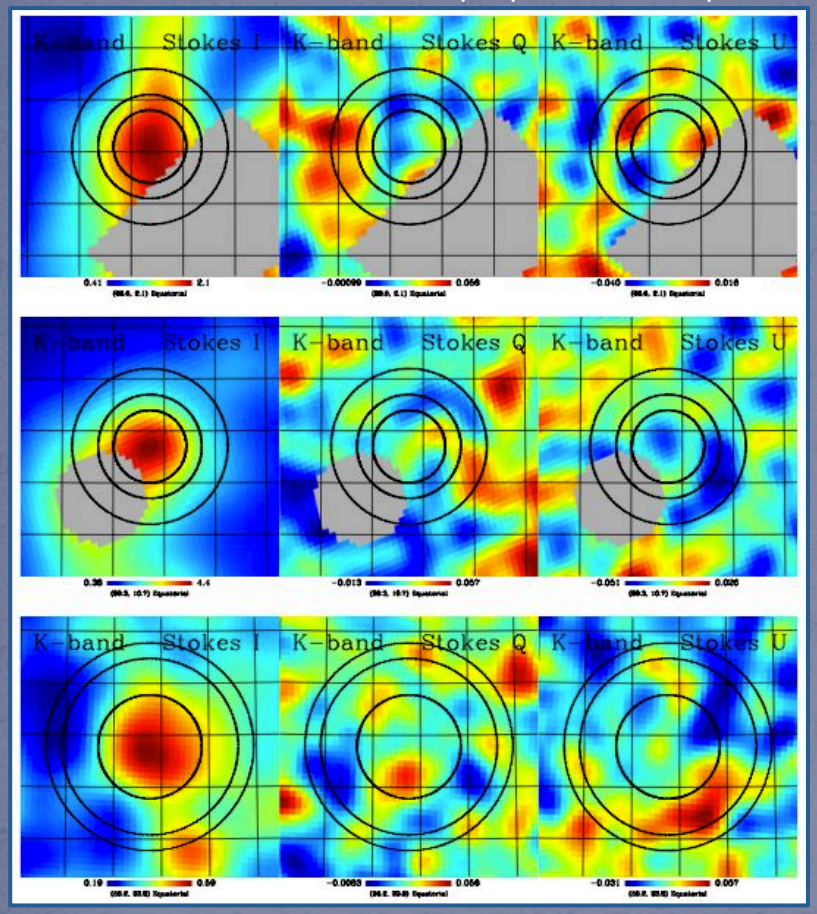
- At 23 GHz we obtained Π < 1.1%.
- It was the first multifrequency analysis of PAME.
- Comparing with PAME models: MD from DL99 and ED from LD00.



Galactic Regions: New Constraints.

Rubiño-Martín et al. 2012 (in prep. for AME Special Issue)

Resolution: 1 deg.
Grid:1degx1deg



LDN1622 (dark cloud):
At 9.5 GHz 2.7% (GBT).

LPH96 (HII region):
At 31 GHz 10% (CBI).

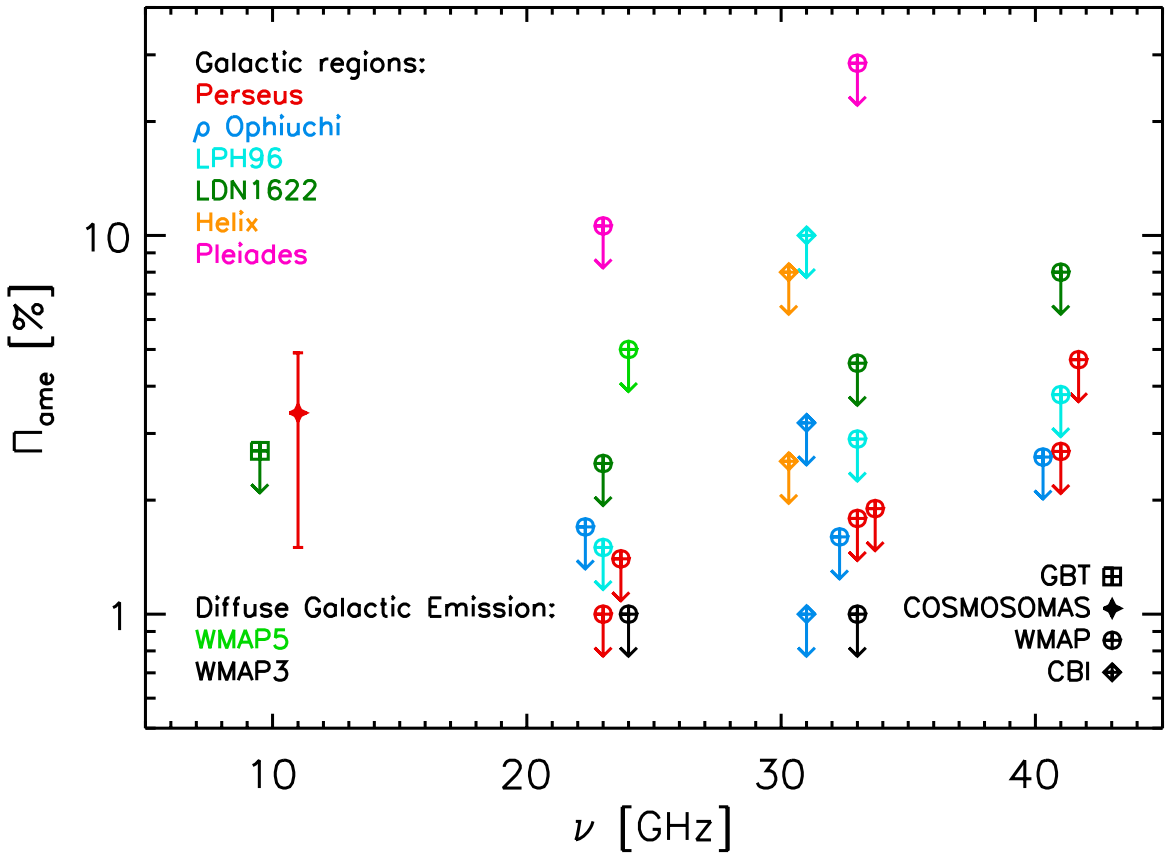
Pleiades (reflection nebula):
First upper limits at 30-40 GHz.

- We considered a fit model: f-f, thermal dust and CMB.
- Polarized upper limits were de-biased following the formalism of Vaillancourt 2006.

2σ upper limits			
name	Π_{ame} (%)		
	23 GHz	33 GHz	41 GHz
Peseus	<1.01	<1.79	<2.69
*LDN*1622	<2.5	<4.6	<8.0
*LPH*96	<1.5	<2.9	<3.8
Pleiades	<10.6	<28.5	<82.2

PAME: Current Observations

From the first table.



Upper limits provide a valuable tool to understand the physical mechanism responsible for AME.

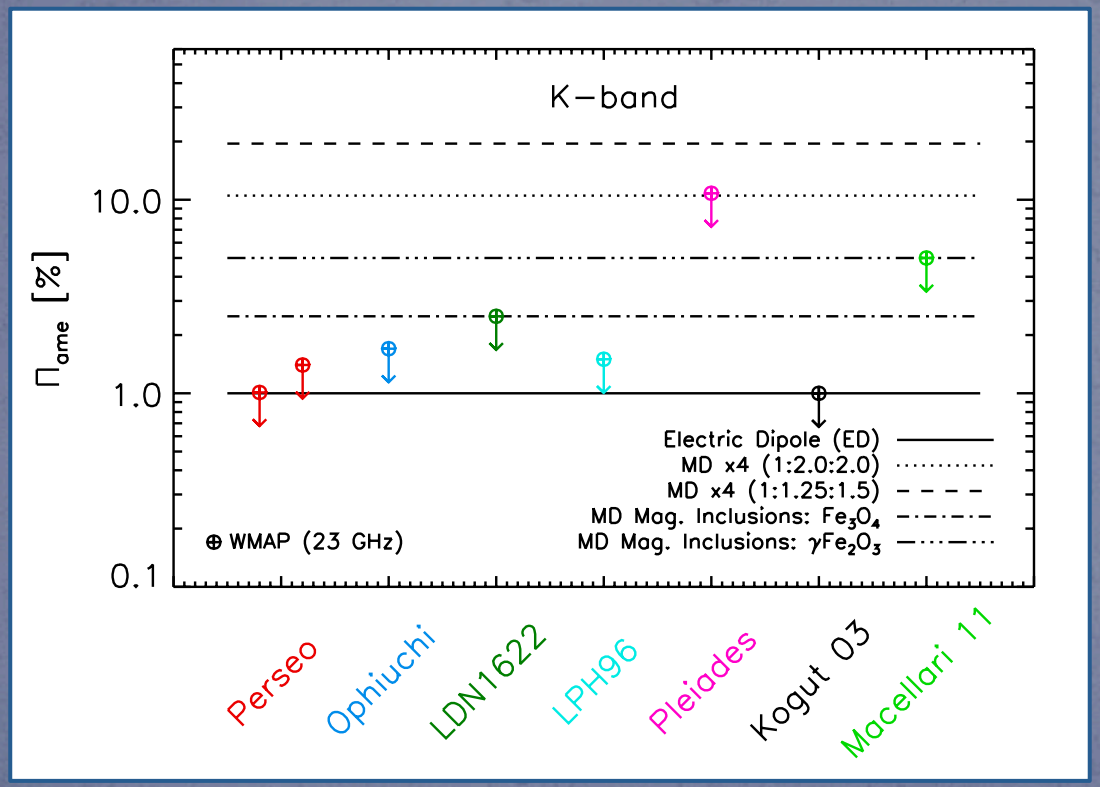
PAME: Observational constraints

- Electric Dipole (ED): Cold Neutral Medium. (LD00)
- Magnetic Dipole (MD):

  MD x4: grains in a single magnetic domain → (DL99)

  Maximal values. → (DH12)

  MD MI: grains with magnetic inclusions. → (DL99 and DH12)



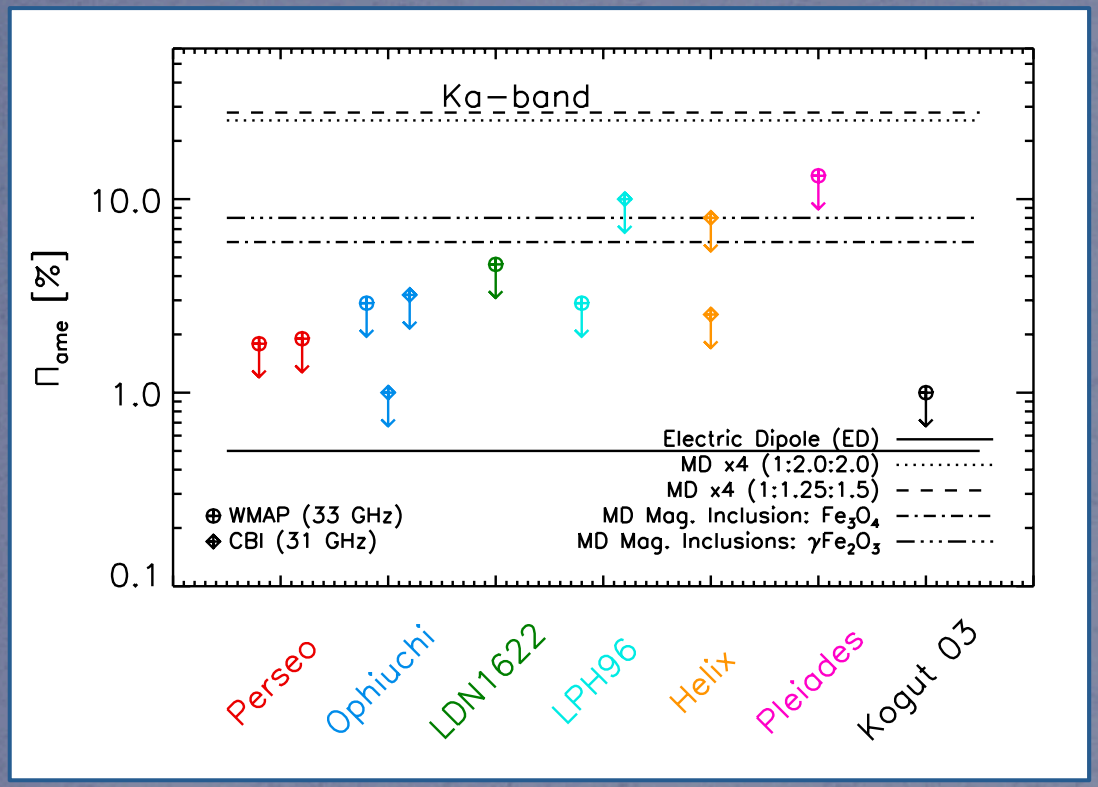
At 23 GHz (approx.):

ED: ≤ 1 % (max. value)

MD x4: 10% - 20 %
In perfectly-aligned.

MD MI: ≤ 5 %
Depending on the Mg. inclusions.

PAME: Observational constraints



At 33 GHz (approx.):

ED: ≤ 0.5 % (max. value)

MD x4: 20% - 30 %
In perfectly-aligned.

MD MI: ≤ 10 %
Depending on the Mg. inclusions.

- We exclude several models based on magnetic emission.
- We cannot rule out the magnetic emission as the physical process responsible for the observed polarization.

… this is the end of first part

PAME as Foreground?

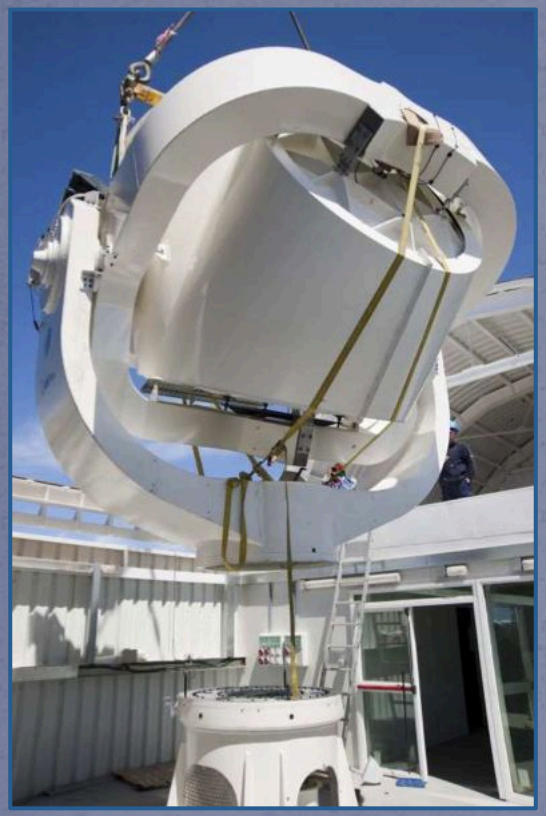
- In intensity, AME is an important foreground at 20-30 GHz.
- Observations provide fractional polarization levels lower than 1% at 20-30GHz.
- Kogut et al. 2007 and Macellari et al. 2011: PAME could be considered as diffuse Galactic emission.

PAME as Foreground?

- In intensity, AME is an important foreground at 20-30 GHz.
- Observations provide fractional polarization levels lower than 1% at 20-30GHz.
- Kogut et al. 2007 and Macellari et al. 2011: PAME could be considered as diffuse galactic emission.
- CMB polarization (B-modes) is a useful tool to study the inflationary epoch.
- Spectral and spatial information about the foregrounds is needed for component separation methods.
- **PAME could affect experiments as QUIJOTE.**

Q-U-I JOint Tenerife experiment

(see Ricardo's and Stuart's talk)

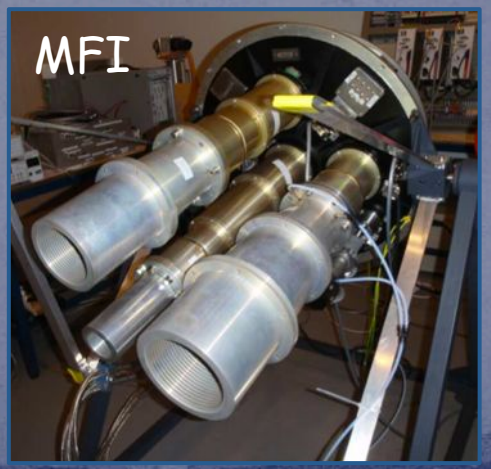


- Located at the Teide Observatory.
- 2 Telescopes and 3 instruments.
- To date: Telescope 1 and MFI instrument.
- **Goals: synchrotron polarization and the detection of B-modes.**

	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

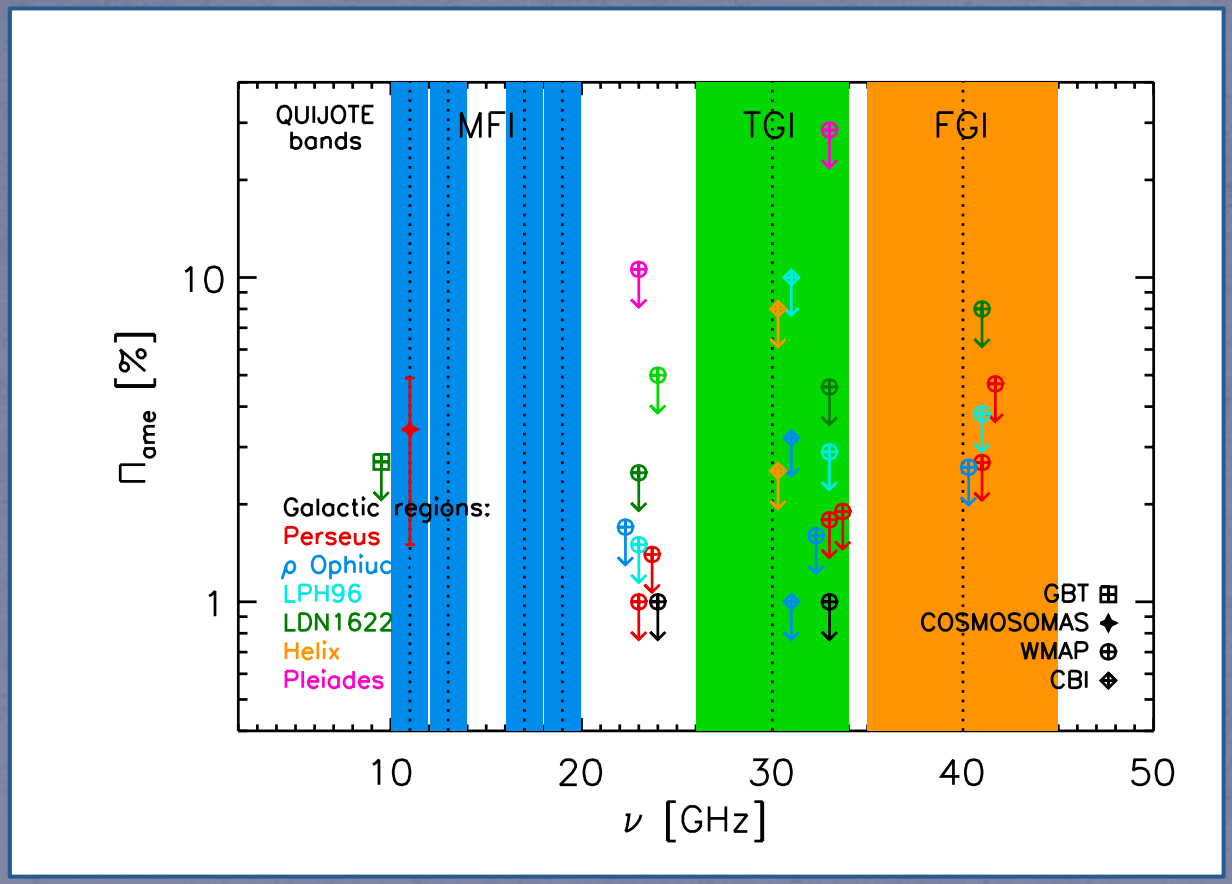
Bands:

- MFI : 11, 13, 17 and 19 GHz.
- TGI : 30 GHz.
- FGI : 40 GHz.



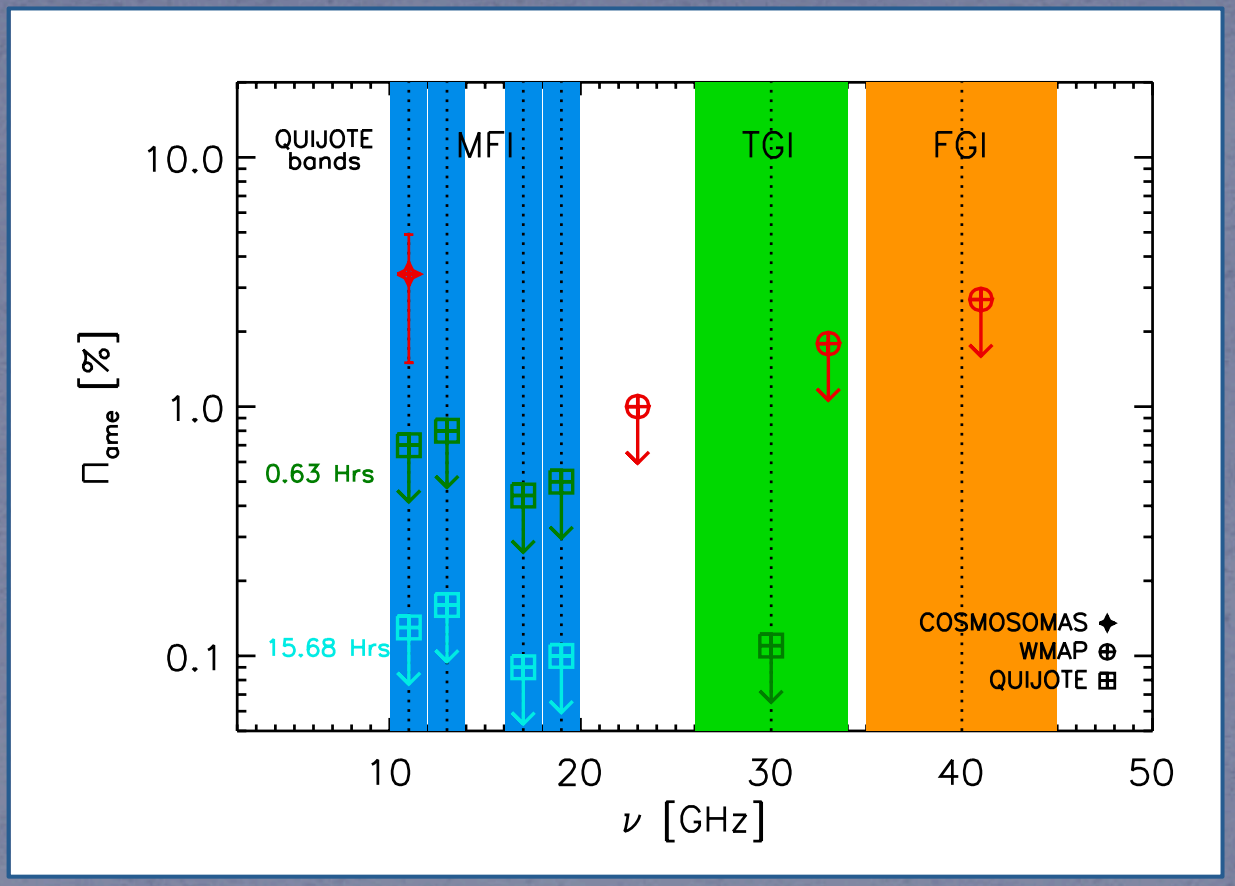
Quijote: frequency bands

MFI (11, 13, 17 and 19 GHz) ; TGI (30 GHz) and FGI (40 GHz)



- MFI covers a range where PAME have been barely studied.
- 3 bands where PAME has not been measured before.

Quijote: PAME on Perseus



Region of 7ºx5º.

- Prediction for the PAME measurements from the nominal sensitivity values of the QUIJOTE-CMB experiment.
- At 19 GHz we need **0.6 h and 16** h to obtain 2σ upper limits of 0.5% and 0.01 % respectively.

Implications on B-modes

- CMB polarization (B-modes) opens a new window to test the inflationary epoch.

- From Page et al. 2007 and Gold et al. 2010:

$$\frac{\ell(\ell+1)C_\ell^{\mathrm{E,B,AME}}}{2\pi} = A_{\mathrm{AME}}\,\ell^{-\alpha}\,\Pi^2_{\mathrm{AME}}$$

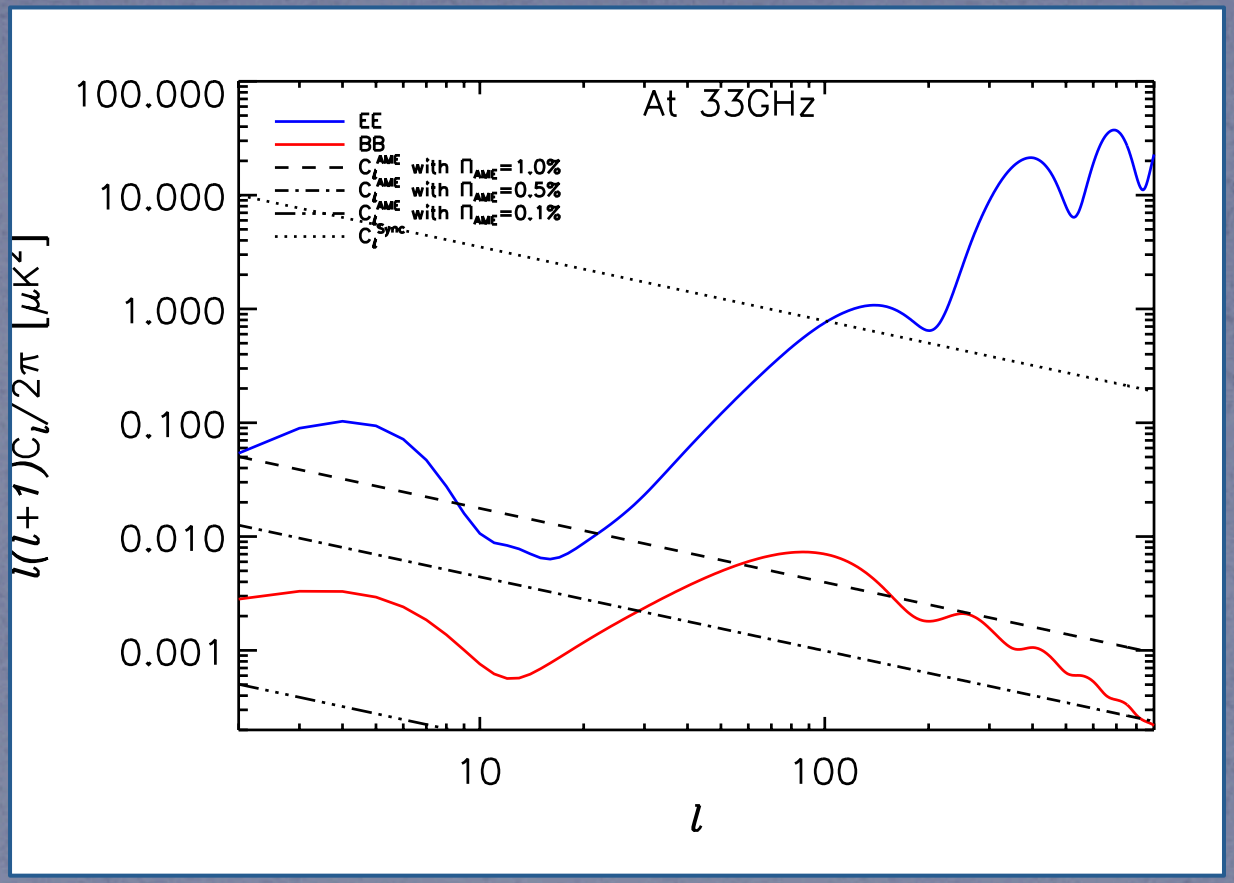
α = -0.6

- From Macellari et al. 2010 we obtain an AME amplitude of 27.6 μK at 33 GHz .

$$(\Delta T)^2 = \sum_{l=2}^{\infty} \frac{2l+1}{4\pi} C_l\, W_l$$

- Π_{ame} = 1%, 0.5% and 0.1% at 33 GHz (review results).

Implication on B-modes



- PAME large-scale contribution could affect the B-mode estimation at 33 GHz.

Conclusions

- At 23 GHz we have ≤1% (2σ), both in individual and large-scale regions.
- In regions with multi-frequency measurements (Perseus and LDN1622), contraints are in agreement with the predictions of the electric dipole.
- MFI instrument of QUIJOTE-CMB will allow us to study the PAME in a different frequency range, with a significant high sensitivity.
- PAME could be an important foreground component in the 20-30 GHz frequency range for B-mode experiments.