# QUBIC The Q&U Bolometric Interferometer for Cosmology A novel way to look at the polarized Cosmic Microwave Background Aniello Mennella for the QUBIC collaboration University of Milan, Dept. of Physics **INFN-Milan**





# Hidden treasures





# Hidden treasures



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# Hidden treasures



The CMB carries the "imprint" of the energy distribution in the primordial universe

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### Spherical harmonics



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## Spherical harmonics



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# **ACDM** universe



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# State of the art



- Current upper limit: r < 0.09
- Measurements require high sensitivity but, especially:
  - Control of instrumental systematic effects
  - Control of astrophysical foregrounds (synchrotron and dust)

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# Worldwide competition

Project	Country	Location	Status	Frequencies	$\ell$ range		$\sigma(r)$ goal	
				(GHz)	value	Ref.	no fg.	with fg.
QUBIC	France	Argentina	2018	150,220	30-200		0.006	0.01
Bicep3/Keck	U.S.A.	Antartica	Running	95, 150, 220 <sup>1</sup>	50-250	[22]	$2.5 \ 10^{-3}$	0.013
CLASS	U.S.A.	Atacama	> 2017	38, 93, 148, 217	2-100	[ <mark>29</mark> ]	1.4 10 <sup>-3</sup>	0.003
SPT3G	U.S.A.	Antartica	2017	95, 148, 223	50-3000	[23]	1.7 10 <sup>-3</sup>	0.005
AdvACT	U.S.A.	Atacama	Starting	90, 150, 230	60-3000	[24]	1.3 10 <sup>-3</sup>	0.004
Simons Array	U.S.A.	Atacama	≥ 2017	90, 150, 220	30-3000	[25]	1.6 10 <sup>-3</sup>	0.005
LSPE	Italy	Arctic flight + Tenerife	2018	43, 90, 140, 220, 245	3-150	[ <mark>30</mark> ]		0.03
EBEX10K	U.S.A.	Antartica	≥ 2017	150, 220, 280, 350	20-2000	[ <mark>28</mark> ]	$2.7 \ 10^{-3}$	0.007
SPIDER	U.S.A.	Antartica	Running	90, 150	20-500	[ <mark>26</mark> ]	$3.1 \ 10^{-3}$	0.012
PIPER	U.S.A.	Multiple	2017?	200, 270, 350, 600	2-300	[27]	$3.8 \ 10^{-3}$	0.008

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CLASS	+ Simons observatory, 2016 – 2021, funded (~ 40 M\$) $\begin{bmatrix} 10^{-3} \\ 10^{-3} \end{bmatrix}$								
SPT3G									
AdvACT	+ CMB S4, 2020 – 2024, not funded yet 10 <sup>-3</sup>								
Simons Arra									
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# QUBIC in a nutshell - the instrument





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Response to a point source in the far field



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Response to a point source in the far field

Signal measured at pixel d<sub>p</sub> at time t  

$$R(d_{p}, t) = S_{I}(d_{p}) + \\
+ \cos(4\omega t)S_{Q}(d_{p}) \\
+ \sin(4\omega t)S_{U}(d_{p}) \\
S_{X}(d_{p}) = \int X(\mathbf{n})B_{synth}^{p}(\mathbf{n})d\mathbf{n}$$

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Response to a point source in the far field



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### The response from equal baselines is in principle the same



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### The response from equal baselines is in principle the same



Self calibration mode:

- Observe an artificial source
- Acquire data with several baselines combinations
- Find instrumental parameters that minimize measurement differences for each baseline

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# QUBIC in a nutshell - sensitivity to r



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Full likelihood analysis

• Noise

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- Lensing B-modes
- Dust foregrounds at Planck-353 level
- Two years of observations with 30% efficiency

# QUBIC site



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# QUBIC site





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# QUBIC site quality



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# QUBIC status and schedule





- End 2017: technological demonstrator tests
- 2018: integration and testing of final instrument
- Mid 2018: shipment to Argentina
- Summer-Fall 2018: installation, commissioning and first light.

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### Conclusions and perspectives

- CMB B-modes are a challenging quest. Measurements limited by systematic effects and foregrounds
- QUBIC responds with a challenging instrument with a design that is robust against instrumental effects.
- The TD will demonstrate the design, the first module will show the scientific potential
- Long-term plans foresee exploitation of the Argentinean site with deployment several modules with a wide frequency coverage

# Collaboration and funding agencies

APC Paris, France CSNSM, France IAS Orsay, France IEF Orsay, France **IRAP** Toulouse. France LAL Orsay, France Università di Milano Bicocca INFN sezione di Milano Bicocca, Italy Università degli Studi di Milano, Italy INFN sezione di Milano, Italy Università La Sapienza, Roma, Italy INFN sezione di Roma, Italy Università di Tor Vergata, Roma, Italy INFN sezione di Roma2, Roma, Italy Maynooth University, Ireland Cardiff University, UK University of Manchester, UK Brown University, USA Richmond University, USA University of Wisconsin, USA Centro Atómico Constituyentes, Argentina GEMA, Argentina

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Comision Nacional de Energia Atomica, Argentina Facultad de Ciencias Astronómicas y Geofisicas, Argentina Centro Atómico Bariloche and Istituto Balseiro, Argentina Instituto de Tecnologias en Detección y Astropartículas, Argentina Instituto Argentino de Radioastronomía, Argentina



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