



## Q&U Bolometric Interferometer for Cosmology

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CMB ground based experiments - Milan 3/4 March 2019



**APC Paris, France** C2N Orsay, France **CSNSM Orsay, France** IAS Orsay, France **IRAP Toulouse, France** LAL Orsay, France Universita di Milano-Bicocca, Italy Universita degli studi di Milano, Italy Universita La Sapienza, 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 Comisión Nacional de Energía Atómica, Argentina Facultad de Cs Astronómicas y Geofísicas, Argentina Centro Atómico Bariloche and Instituto Balseiro, Argentina Instituto de Tecnologías en Detección y Astropartículas, Argentina Instituto Argentino de Radioastronomía, Argentina





















1 baseline





1 baseline



total signal (all baselines)

## Quasi optical correlator





## Self Calibration



#### Unique possibility to handle systematic errors

- Use horn array redundancy to calibrate systematics
- In a perfect instrument redundant baselines should see the same signal
- Differences due to systematics
- Allow to fit systematics with an external source on the field

Unique specificity of Bolometric Interferometry ! Bigot-Sazy et al., A&A 2013, arXiv:1209.4905



Redundant baselines : same Fourier Mode







## **Bolometric Interferometry**

#### Primary horn array

## Synthesized beam (on the sky)





#### 150-220 GHz, 20x20 horns, 13 deg. FWHM, D=1.2 cm

Synthesized beam used to scan the sky as with an imager



## Spectro Imaging



- Synthesized beam:
  - $\star$  Depends on horns configuration
  - ★ AND on frequency !
    - ex: a point source emitting at 140 and 160 GHz
- There is spatial + frequency information !
- Multi-frequency map-making with the same TOD
  - ★ Spectral resolution  $\Delta v/v \sim 0.05$
  - $\star$  Shown to be quasi-optimal with simulations
  - $\star$  article being finalized



## **QUBIC Spectro Imaging**



QUBIC – Steve Torchinsky





## **QUBIC** Layout



- Outer cryostat: Roma
- 1K Box / detectors: APC, CSNSM / IRAP
- Fridges: Manchester
- Optics: Roma / Maynooth / Cardiff

Currently cold and under test at APC





## **QUBIC Hardware**



cryostat manufactured by Roma La Sapienza



## **TES Detector Array**





QUBIC TES array Array P87 ASIC1 black curves, data from 2018-12-14 16:08, T<sub>bath</sub>=348.000mK Array P87 ASIC2 blue curves, data from 2018-12-14 16:08, T<sub>bath</sub>=348.000mK bad pixels in black background. 214 good pixels out of 256 = 83.6% V<sub>minow</sub> from red to blue (1.5V to 8.5V)





TES fabrication: CSNSM Readout electronics: APC & IRAP

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## Optics Box at 1K



M1 Initial measured points - Mirror in HexRF



#### Structure: APC Mirrors + alignment: Milano, Roma, APC





## Cryo system

#### 1K and 300mK He4 fridges: U. Manchester



Both cycled successfully inside the QUBIC cryostat





## Cryo Optical Components

#### Filters, HWP, Polarizer: Cardiff







## Back to Back Horn Array

#### B2B platelets horn-array Milano Statale



#### Switches and electronics Milano Bicocca + APC







#### QUBIC HWP Rotator Roma - La Sapienza







# QUBIC as seen from the Calibration Source

reflection of window in flat mirror

























QUBIC TES array Array P87 ASIC1 black curves, data from 2019-01-29 13:21, T<sub>bath</sub>=376.113mK Array P87 ASIC2 blue curves, data from 2019-01-29 13:21, T<sub>bath</sub>=376.113mK

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## Scanning in Azimuth







## Synthesized Beam Profile



#### scan of beam across one pixel





## Scanning in Frequency



![](_page_25_Picture_0.jpeg)

## Summary

![](_page_25_Picture_2.jpeg)

#### QUBIC is a novel instrumental concept

- ★ First Bolometric Interferometer
- $\star$  Dedicated to CMB polarimetry and inflationary physics
- **\star** High sensitivity with ~2000 TES bolometers
- $\star$  Optimized to handle systematics:
  - Self Calibration allowed by observing individual fringe patterns (Unique to QUBIC)
- \* Spectro-Imaging with two physical bands (150 / 220 GHz) and 5-10 subbands:
  - Foregrounds contamination control and removal with up to 10 bands (unique to QUBIC)
- ★ <u>Target :</u>
  - First module (150-220 GHz):  $\sigma(r)=0.01$  (incl. dust)
  - Stage IV evolution of QUBIC  $\sigma(r)=0.01$  hopefully through a wider European collaboration + CMB-S4 tube(s)
- QUBIC deployment is on the way:
  - $\star$  TD Integration and test ongoing at APC
  - $\star$  Initial Calibration measurements in the lab
  - ★ First light in Argentina end-2019
  - ★ Upgrade to Full focal plane and 20x20 horn array in 2020