Revista Mexicana de Astronomía y Astrofísica Serie de Conferencias, 60, 250-251, (2026)

OPEN ACCESS https://doi.org/10.22201/ia.14052059p.2026.60.203

"XVII LARIM", Montevideo, Uruguay, November 27 - December 1, 2023.Volume Editors: Gonzalo Tancredi, Cecilia Mateu & Juan José Downes

The QU Bolometric Interferometer for Cosmology: status and prospects

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Keywords: *Cosmology: Cosmic background radiation*

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QUBIC is an bolometric interferometer telescope installed at the Puna, in the Salta province of Argentina, to measure the polarization of the CMB, searching for the CMB primordial B modes, that will be an indirect evidence of the inflationary period of the Universe. Here, we update on its current status and prospects.

The Q&U Bolometric Interferometer for Cosmology (QUBIC, Hamilton et al., 2022) is the first bolometric interferometer designed to measure the primordial B-mode polarization of the Cosmic Microwave Background (CMB). Bolometric interferometry (BI) is a novel technique that combines the sensitivity of bolometric detectors with the ability to control the systematic effects enabled by the interferometry. Both sensitivity and systematic control are very important since the primordial B-modes is a very faint signal. Thanks to the frequency dependence of its synthesized beam, QUBIC presents a unique feature, the so-called "spectral imaging", i.e., the ability to recover the sky signal in several sub-bands within the physical band during data analysis. This feature provides an in-band spectral resolution of $\Delta\nu/\nu \sim 0.04$ that is unattainable by a traditional imager. This is a key tool for controlling the Galactic foreground's contamination.

Since its inauguration, QUBIC has been in commissioning stage, during which, several studies related to the calibration of the instrument have been carried out. Since the telescope is unique in its design and architecture, all the pipelines had to be specifically developed for those purposes. Studies such as the corrections of flux jumps, the measurement of time constants of the detectors, the angular resolution at different frequencies, and more, have been carefully carried out. Many of these studies were published in eight papers for a special edition of JCAP (2023), and other articles are currently in preparation.

It is known that multi-frequency observations are needed to constrain galactic foregrounds and isolate the CMB signal. Many experiments are designed in several spectral bands to have information at different frequencies. Also, there are many methods in the literature to perform the component separation. QUBIC will allow to do the component separation at the map-making level (Regnier & et al., 2024, in prep.), as well as to produce maps at different number of subfrequencies within the wide spectral band (Chanial & et al., 2024, in prep.).

However, foreground emission may be more complex than anticipated. Not taking into account these complexities during component separation can lead to a bias on the recovered tensor-to-scalar ratio.

In Regnier et al. (2024) and Manzan et al. (2024), we investigate how the spectral imaging capability of the BI can help in diagnosing the presence of foreground residuals in case of simplied foreground modeling. We assume that line-of-sight frequency decorrelations are present in the dust emission but are not accounted for during component separation and we compare the estimated tensor-to-scalar ratio, r, after a Monte-Carlo analysis based on a parametric component separation, in the case of the next generation of ground-based CMB experiment, CMB-S4 (Abazajian et al., 2022), and of a hypothetical version of the same experiment based on BI, CMB-S4/BI. We find that the constrain on r depends on the number of reconstructed subbands, an evidence of the presence of residuals in the foreground cleaning. This would not be possible to achieve with normal imagers, even when many frequencies are used.

We highlight the potential of BI for CMB polarization experiments that will be challenged by complex foregrounds in their quest for B-modes detection.

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