

Final project report

<i>Project ID</i>	2004/11.01
<i>Title</i>	ACDC: Automated Cryogenic Detector at Concordia
<i>Principal investigator</i>	P. de Bernardis
<i>Institution</i>	Dipartimento di Fisica, Università La Sapienza
<i>Email</i>	paolo.debernardis@roma1.infn.it
<i>Duration</i>	2 years
<i>Assigned funding</i>	150.000,00 Euro

Activities and results

We have built a custom cryogenic system at 0.3K which can be operated automatically in Dome-C during the Antarctic winter, without the need of cryogenic consumable fluids. We have also developed a detector array (81 detectors sensitive at 145 GHz) to be cooled by the cryogenic system above.

The main purpose of this system is the measurement of the polarization of the Cosmic Microwave Background. The cryogenic system has been operated for two summer campaigns in Dome-C, cooling the BRAIN pathfinder experiment. The compressor of the pulse tube refrigerator is mounted inside a protective shelter, which uses the heat developed by the compressor to regulate the internal temperature within the operating range of the compressor and of the system electronics. The cold head and the cryostat are mounted outside the shelter, so that the detector array can operate at the focus of a millimeter-wave telescope. Using indium seals the cryostat can operate at temperatures as low as -100°C. The inflow and outflow tubes of the pulse-tube refrigerator are heated circulating around them hot air from the shelter.

The detectors are kinetic inductance resonators, where microwave photons break the cooper pairs in a superconducting resonator, moving their resonance frequency. These detectors are intrinsically frequency-domain multiplexed, and can be replicated in large arrays without the need of a large number of electrical connections between the room temperature electronics and the cryogenic focal plane. We have carried out extensive tests of these detectors, demonstrating that their noise equivalent power is of the order of 100 aW/sqrt(Hz), low enough to be dominated by atmospheric noise in the atmospheric window at 145 GHz.

We have operated the cryogenic system and the array in Dome-C in the framework of the BRAIN Pathfinder experiment, in 2005, 2006 and 2009, allowing a full measurement of the polarization properties of the Antarctic atmosphere above Dome-C in the summer. The system is now ready for operation in the Antarctic winter.

Products

A – papers in scientific magazines

- 1) G. Polenta, P.A.R. Ade, J. Bartlett, E. Breelle, L. Conversi, P. de Bernardis, C. Dufour, M. Gervasi, M. Giard, C. Giordano, Y. Giraud-Heraud, B. Maffei, S. Masi, F. Nati, A. Orlando, S. Peterzen, F. Piacentini, M. Piat, L. Piccirillo, G. Pisano, R. Pons, C. Rosset, G. Savini, G. Sironi, A. Tartari, M. Veneziani, M. Zannoni, *"The BRAIN CMB polarization experiment"*, *New Astronomy Reviews*, 51 (2007) 256-259
- 2) M. Calvo, C. Giordano, R. Battiston, A. Cruciani, P. de Bernardis, B. Margesin, S. Masi and A. Monfardini, *"Microwave Kinetic Inductance Detectors for Long Duration Balloon experiments"* *Mem. S.A.It. Vol. 79*, 953 (2008)

B – book chapters

- 1) S. Masi, P. de Bernardis, *"Measurements of CMB Polarization with bolometers"* in *"Cosmic Polarization"*, pg. 46, R. Fabbri editor, Research Signpost, (2006) ISBN 81-308-0089-6

C - proceedings of international conferences

- 1) P. de Bernardis, *"CMB Observations from Dome-C"*, Proc. of the 2nd ARENA Conference "The Astrophysical

Programma Nazionale di Ricerche in Antartide (PNRA)

- Science Cases at Dome C", Potsdam, 17-21 September 2007, H. Zinnecker, H. Rauer & N. Epchtein eds., EAS Publications Series, **33**, 175-182 (2008), EDP Sciences.
- 2) P. de Bernardis, D. Barbosa, Y. Giraud-Heraud, M. Gervasi, E. Kreysa, B. Maffei, S. Masi, P. Mauskopf, F. Pajot, L. Verde, "Cosmic Microwave Background science from Dome-C", in 3rd ARENA Conference: "An Astronomical Observatory at CONCORDIA (Dome C, Antarctica)", EAS Publications Series, **40**, 391-398 (2010), L. Spinoglio and N. Epchtein eds., ISBN: 978-2-7598-0485-6
 - 3) M. Calvo, C. Giordano, P. de Bernardis, R. Battiston, A. Cruciani, B. Margesin, S. Masi and A. Monfardini, "Development of KIDs detectors for large submillimetric telescopes", in 3rd ARENA Conference: "An Astronomical Observatory at CONCORDIA (Dome C, Antarctica)", EAS Publications Series, **40**, 443-450 (2010), L. Spinoglio and N. Epchtein eds., ISBN: 978-2-7598-0485-6
 - 4) D. Barbosa, P. de Bernardis, M. Gervasi, Y. Giraud-Héraud, E. Kreysa, B. Maffei, S. Masi, P. Mauskopf, F. Pajot and L. Verde, "Foregrounds: Unveiling the Galactic Weather to the CMB", in 3rd ARENA Conference: "An Astronomical Observatory at CONCORDIA (Dome C, Antarctica)", EAS Publications Series, **40**, 437-442 (2010), L. Spinoglio and N. Epchtein eds., ISBN: 978-2-7598-0485-6

D – proceedings of national meetings and conferences

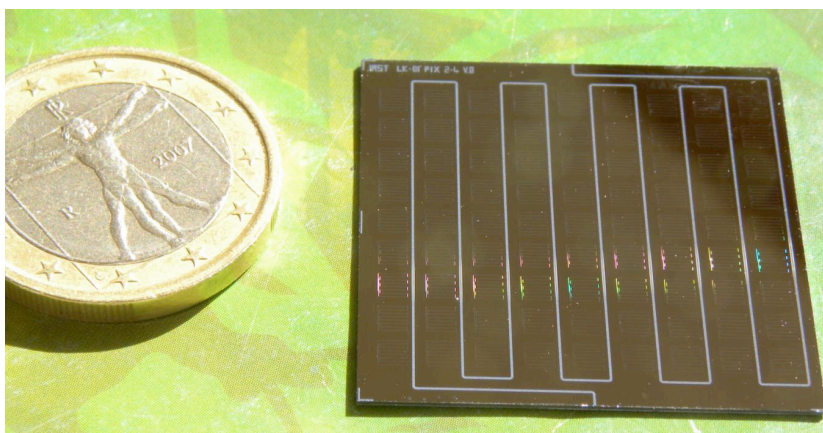
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E – thematic maps

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F – patents, prototypes and data bases

- 1) Cryogenic system, including a pulse-tube cooler, and 3He/4He refrigerator, a cryostat with vacuum window and filters for millimeter-waves.
- 2) Insulation system and active heaters, with remote control, to operate the cryogenic system above in the harsh conditions of Dome-C.
- 3) Prototype Kinetic Inductance Detector Array, consisting of a wafer with 81 cryogenic resonators (81 pixels), optimized for operation at 150 GHz. (see picture below).



G – exhibits, organization of conferences, editing and similar

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H - formation (PhD thesis, research fellowships, etc.)

- 1) "Assegno di ricerca" for two years at the Physics Department. Title: Mosaico di rilevatori ad induttanza cinetica per cosmologia millimetrica.

Research units

Dipartimento di Fisica, Università di Roma La Sapienza:
P. de Bernardis, S. Masi, E. Battistelli, G. Polenta (ASDC), A. Schillaci, S. Peterzen (ISTAR), M. Maiello (Università di Siena), R. Sordini.

Date: 28 march 2010

Notes