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Antarctic activities of the Milano Bicocca Radio Group: a Status Report

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Abstract. The Milano Bicocca Radio Group has a long experience of astrophysical and cosmological observations made at the Amundsen Scott Base at South Pole, Terra Nova Bay and at Dome C with existing equipment and ad hoc experiments. Present activities are in the field of CMB Polarimetry and Radiometry at mm and sub-mm wavelengths.

1. Introduction

Because of the peculiar transparency and stability of the atmosphere above it, the Antarctic Plateau is one of the best place on the Earth for observations at microwave, mm and sub-mm wavelengths (see for instance Stark et al. (1998) and Ajello et al. (1995)). Therefore it is excellent for studies of the fine structures of the Cosmic Microwave Background (CMB), relic of the Big Bang: spectral distortions (deviations from the spectral Planck shape), spatial anisotropies, residual polarization, Sunyaev Zeldovich effect. And observations of these features are among the most powerfull tools of present days Observational Cosmology. In the past the former Milano (now Milano Bicocca) Radio Group searched for CMB spectral distortions from Antarctica. In 1989 and 1991, in collaboration with LBL-Berkeley, absolute radiometers were installed near the Amundsen Scott base at South Pole. They were used to measure the CMB frequency spectrum at low frequencies (Sironi et al. (1991), Smoot et al. (1991), Bersanelli et al. (1993) and De Amici et al. (1993)). Stimulated by the quality of the Antarctic site Milano planned, in collaboration with Giorgio Dall'Oglio, new observations from Baia Terra Nova (BTN). This project, called MEGA (Sironi et al. (1995)) was part of GEM (De Amici et al. (1994)), a large international collaboration created with the aim of measuring the very low frequency spectrum of the diffuse background radiation. It included the construction of a steerable parabola, to be installed near the BTN italian base, for observations of the diffuse radiation between 0.6 and 2.5 GHz. In 1994 extensive measurements of the level of radio interferences at BTN were made by Milano, the complete project of the apparatus was prepared and a contract for the construction of the antenna

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feeders was signed by the Italian Antarctic Program. Unfortunately when the antenna feeds were completed and tested the program was halted because of fund shortage. The antarctic activities of the Milano Group however continued. Today they rotate around three lines: i)search for residual polarization of the CMB, ii)developing low noise coherent detectors essential for astrophysical an cosmological observations at mm and sub-mm wavelengths iii)exploiting the potential of the antarctic site for mm and sub-mm astrophysics and cosmology.

2. CMB Polarimetry

Detection of polarization in the spatial distribution of the CMB confirms the cosmological nature of the anisotropies observed in the CMB distribution and allows to break the degeneracy of the models of the Universe which fit the anisotropy data. In spite of this interest CMB polarization has been detected only very recently, after years of efforts made by many groups. The first detection has been communicated at the end of 2002: it was obtained with an experiment, DASI, installed near the Amundsen Scott base at South Pole (Kovac et al. 2002). Even more recently WMAP, a space experiment which carries on observation at the L2 point, gave new evidence in favour of the existence of CMB polarization and provided additional information (Kogut et al. 2003). In spite of their preliminary nature these results immediately improved our knowledge of the thermal history of the Universe. We have now evidence that sometime after recombination there was reionization which produced additional scattering of the CMB in a way definitely higher than previously expected (see for instance Zaldarriaga (2002)). In particular the MAP results show that CMB polarization is important not only at small angular scales. Therefore it is worth continue the efforts for detecting it also at large angular scales. The Milano group built and operates a correlation polarimeter with the aim of studying the polarization of the CMB at large angular scales (7^o and 14^o) from the Antarctic Plateau. Two prototypes were prepared with the financial support, among others, of the italian antarctic program. They were tested at BTN (Sironi et al. 1998a) in 1994 and at Dome C (Sironi et al. 1998b), (Zannoni 2000) in 1998. Following these tests the system has been improved (Sazhin et al. (1999), Spiga et al. (2002), Sironi et al. (2002) and Gervasi et al. (2003)). It is now in operation at Testa Grigia (3600 m a.s.l.) on the Italian Alps, ready to be brought to Antarctica for observations also in winter. The system (see fig.1) allows studies of linear and circular polarization and includes phase modulation and synchronous detection for stability and $1/f$ noise reduction. To further improve the stability the system is mounted inside a thermally isolated polar tent which protect it against the harsh conditions of the winter weather on the Antarctic Plateau or on high mountains (see fig. 1). We are now studying optics necessary to bring the polarimeter angular resolution to $\simeq 0.1^o$. The aim is to study the angular power spectrum of the polarized signals detected and disentangle the CMB polarized component from the polarized foregrounds which hamper observations, taking advantage of the different statistical properties of these signals (Sazhin et al. (2002)). Beside using his own polarimeter the Milano Bicocca group is collaborating: i)with Lucio Piccirillo and Paolo Debernardis to a project for a third generation polarimeter sensitive to the B mode component of the CMB polarization to be installed at Dome C (Piccirillo (2003)), ii)to BAR-SPOrt, a correlation polarimeter derived from the space experiment SPOrt SPOrt (2003). It will measure the CMB polarization from a stratospheric balloon, during long duration flights in the polar regions Carretti et al. (2002).

3. Low Noise coherent detectors

For exploiting the transparency of the Antarctic Atmosphere at mm wavelengths the Milano Bicocca group, in collabora-

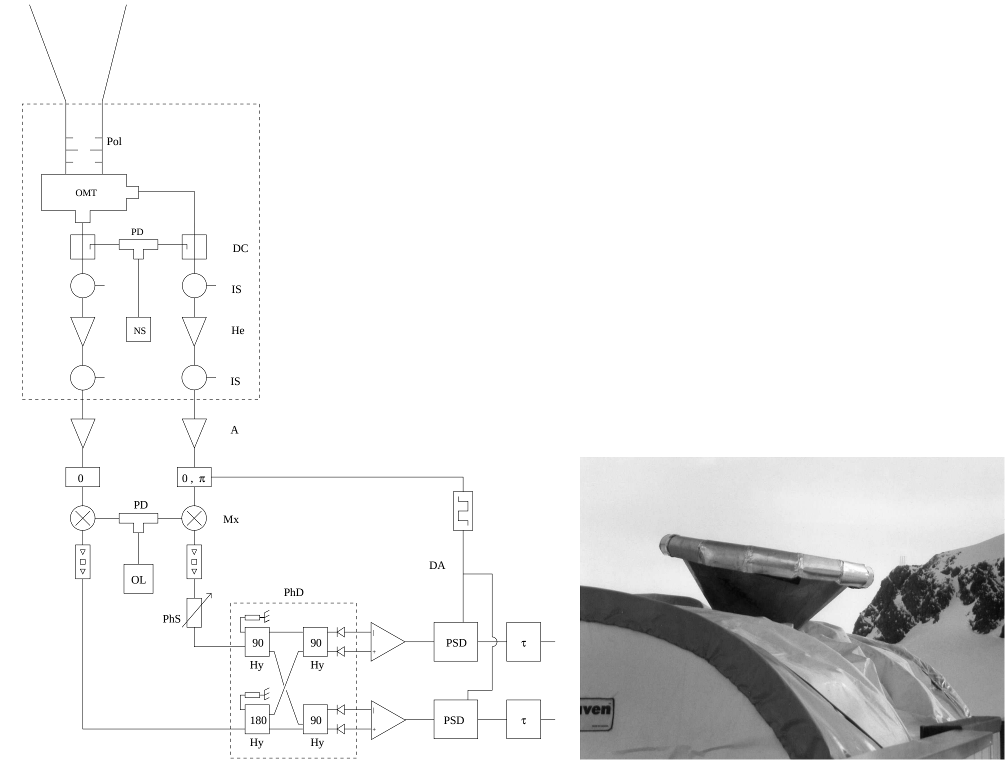

Fig. 1. The Milano Correlation Polarimeter. Left panel: Block diagram. Right panel: the Milano Polarimeter at Testa Grigia. The system front end is cooled to 20 K. By inserting an iris polarizer (Pol) between the antenna, a corrugated circular horn, and the Orthomode Transducer (OMT) the system is sensitive to linear polarization (outputs proportional to the Stokes Parameters U and Q). When the iris polarizer is absent the system is sensitive to Circular Polarization (outputs proportional to the Stokes Parameters Q and V). Correlation is performed by an hardware Hybrid Phase Discriminator (PhD) followed by a pair of differential amplifiers and time integrations. System stability and 1/f noise rejection are improved by phase modulation and phase sensitive detection (PSD). The angular resolution of 14^o can be increased to 7^o by adding a proper extension to the horn. The entire system is housed in a polar tent to protect it against harsh weather condition. Only the horn, surrounded by a ground shield visible in the picture, comes out from the tent.

tion with the Arcetri section of IRA-CNR and with IEN Galileo Ferraris in Turin, developped low noise SIS (Superconductor - Insulator - Superconductor) mixers for frequencies up to 350 GHz (Sironi et al. 1996). The junctions are built and assembled inside the electromagnetic structure which houses them at IEN (Sironi et al. 1996). Tests and preparation for astrophysical observations are made by the Milano and Arcetri Group in Milano where we prepared a criogenic chamber, supported by a 4 K mechanical cryocooler (see fig. 2), and have electronic equipment for tests up to 350 GHz. At present we are assembling a radiometer with a 10% bandwith centered at 94 GHz and MASTER, a system of three radiometers which op-

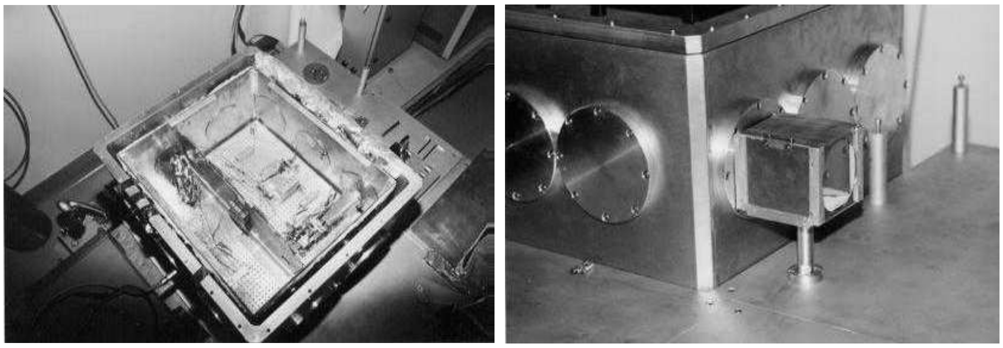

Fig. 2. The Criogenic Test Chamber. It can accomodate flux collector, SIS mixer and criogenic IF amplifier. All the components can be cooled to 4 K by a mechanical cryocooler. A 70 K shield and sheets of superinsulating material minimize thermal inputs from the ambient. The signals of Source and Local Oscillator are generated outside the chamber, redirected by a set of mirrors and injected into the flux collector through vacuum tight windows. Left Panel: top view of the open chamber. Right Panel: external view of the chamber

erate around 94, 220 and 345 GHz. They can be used for radiometry, or coupled to an Acousto - Optic Spectrometer provided by the Arcetri group, for spectroscopy (Battistelli et al. (2002) and Tartari et al. (2003)).

4. mm and sub-mm observations and projects

We are planning observations f the Sunyaev Zeldovich effect using our system MASTER coupled to existing telescope in Antarctica or other sites (Tartari et al. (2003)). The same system and the 94 GHz system can be used also for studies of regions of stellar formation. To gain experience in this astrophysical activity, in collaboration with the group of A.Stark we made studies of Bok globules with the AST/RO telescope at South Pole (Scappini et al. (2000)). Being convinced that mm and sub-mm astronomy will become more and more important in the future and that one of the best place for this activity is the Antarctic Plateau, the Milano Bicocca group is active in submitting projects for the construction on the Antarctic Plateau of International Facilities (e.g. Sironi (1998)). We contributed to the submission to the NSF of the project for a 10 m diameter telescope, an international facility to be installed at South Pole (Stark et al. (1998))and got support by the italian antarctic program. Moreover we have been in contact with Giorgio Dalloglio group for the proposal of a 4-5 m sub-mm telescope at Dome C and are among the proponents of the International Center illustrated at this Conference by Luca Olmi (Calisse et al. 2003).

5. Conclusions

The Milano Bicocca group gained in the past the experience and the instrumentation necessary to carry on astrophysical and cosmological observations from the Antarctic Plateau also in winter time. We got them through the financial and logistical support of Italian Antarctic Program and through collaboration to programs supported by NSF for observations at South Pole. We are ready to continue, but we have to know as soon as possible when the international base Dome Concordia at Dome C will become fully operational in winter, and the support the italian authorities will provide.

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