

THE SPORt RADIOMETERS

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ABSTRACT

The Sky Polarization Observatory (SPORt) is an instrument to be operating onboard the International Space Station during Early Operation Phase, aimed to measure the linear diffuse sky polarization in the frequency range 22-90 GHz. The SPORt payload is presented with particular emphasis to the radiometer architecture, designed for very high sensitivity polarization measurements requiring careful optimization of systematics.

INTRODUCTION

The last decade of the 20th century has seen great advances in observational cosmology due to the NASA-COBE DMR (Smoot et al, 1991) space mission in the first place. More recently BOOMERanG (de Bernardis et al, 2000) and MAXIMA (Lee A.T. et al, 2001) balloon experiments as well as DASI (Halverson et al, 2001) from ground have definitely confirmed that the early Universe was not completely homogeneous. All these experiments have collected significant data on the Cosmic Microwave Background Radiation (CMBR), a radiation filling up the Universe and representing the relic of the Big Bang. An important feature of the CMBR is that it is really almost isotropic but not quite, as proved by the tiny temperature fluctuations ($\Delta T/T \sim 10^{-5}$) that have been observed by several experiments at different angular scales. Fundamental information is encoded in the angular power spectrum of these CMBR anisotropies, thought to be the seeds of the present cosmological structures.

The detailed structure of this spectrum allows to test different cosmological models and to increase the precision in the determination of the Universe parameters. In addition, the CMBR can be (linearly) polarized. However, while further anisotropy information with greater sensitivity is expected shortly from present and future experiments, polarization signals are expected to be at least one order of magnitude weaker than the anisotropy. But the polarization of CMBR is essential to remove degeneracies between important cosmological parameters and it represents today's challenge for experimenters (Figure 1).

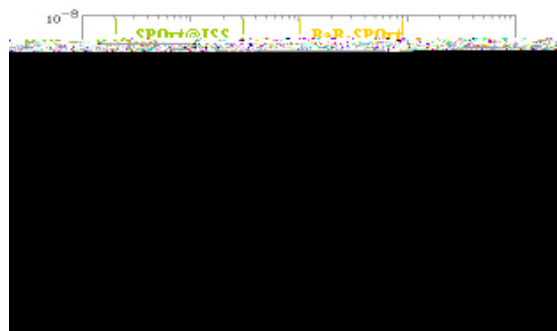


Fig. 1: The expected polarization signal respect with the anisotropy

The current available technology seems to be already suitable to attain the first detection of the low polarization signals when combined with proper observing strategies. The problem of foreground subtraction, in fact, plays a fundamental role: the galactic polarized emission (mainly synchrotron) must be known with great precision to single out genuine CMBR polarization (Cortiglioni & Spoelstra, 1995). The SPORt (Sky Polarization Observatory) Program (Cortiglioni et al, 2002) is facing the problem by preparing two experiments: SPORt@ISS (Carretti et al, 2002) and BaR-SPORt (Zannoni et al, 2002). The first one has the task to provide full-sky accurate measurements of the microwave sky

(foregrounds and CMBR polarization) at large angular scale, onboard the International Space Station. The latter is an experiment to be flown onboard stratospheric balloons for observing sub-degree angular scales. The SPORt Program also includes “low frequency” ground observations of some sky regions for complementary investigations and calibrations. Furthermore, such an approach is fundamental to design the best strategy for future forth generation experiments on CMBR.

THE MICROWAVE SKY

The microwave sky is really unknown at frequencies higher than few GHz, especially in its linearly polarized component, which has been properly mapped only in regions close to the galactic plane. High Galactic latitudes have been surveyed extensively - but undersampled - at frequencies not higher than 1411 MHz (Figure 2). Angular Power Spectra (APS) of the Galactic synchrotron polarized radiation have been given an increasing attention in these years, because of the need for an angular-scale-dependent separation between the CMBR and the polarized foreground.

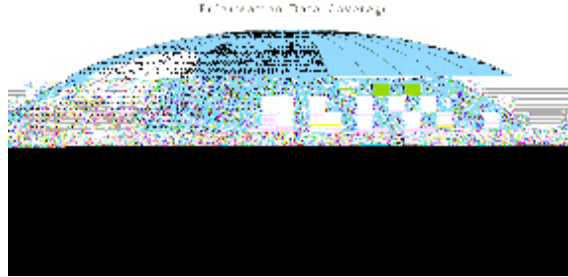


Figure 2: The available polarization data up to 2.7 GHz

Unfortunately, good polarization maps are necessary to calculate APS, at different frequencies and with sub-degree angular resolution.

The major problem is that at a frequency as high as few GHz the Galactic polarized emission gets in the order of mK, in terms of antenna temperature, rapidly decreasing to tens of μK due to its steep spectrum. Most common Radiotelescope receivers do not have the long-term sensitivity required for appreciating such low polarized signals as those generated by galactic synchrotron, free-free and dust emission in the microwave and sub-millimeter domain. Moreover, the angular resolution of most modern Radiotelescopes is too high to allow large-scale surveys extending at high Galactic latitudes, as required by the very careful foreground subtraction in CMBR polarization measurements. Additional restrictions come from the limited availability of polarimetric facilities and from the atmospheric emission fluctuations. For these reasons each experiment aimed at investigating the CMBR polarization must provide its own strategy for foreground removal, which is usually based on multifrequency observations.

SPORt@ISS

The International Space Station (ISS) is the largest manned structure to be built in space. Five space agencies (USA, Russia, Canada, Japan and Europe) are contributing to the realization of this huge laboratory flying around the Earth for more than 10 years with a permanent crew. Its low polar orbit (350-450 km of altitude, 51.2° of inclination) with a 90 min. period will allow

astrophysics. A bottom-up study of a 4th generation CMBR space mission devoted specifically to polarization would greatly benefit from the accumulated experience within the SPOrt@ISS project. The SPOrt payload is realized by a consortium of industries led by ALENIA Spazio, under contract with the Italian Space Agency.

THE SPOrt@ISS INSTRUMENT

Since the beginning it has been realized that such ambitious goals cannot be reached using “standard” technology, the one available from telecommunication applications representing the only one commercially available. Another baseline is that a real polarization measurement needs the direct evaluation of the Stokes parameters Q and U representing the (linear) polarization.

The SPOrt Team has developed a phase-switched receiver architecture (Fig. 3) where the two circular components are correlated onboard by a correlation unit based on a Hybrid Phase Discriminator. Because of these really severe requirements all the passive waveguide components have been customized by the Team, aiming at the minimization of systematics (offset <50 mK). The total rejection to the unpolarized component (3K) is ≈70 dB. An internal calibrator provides full amplitude and phase calibration pixel by pixel, every 105 sec. The front-ends (Polarizer+OMT+LNAs) are actively cooled at ≈ (80±0.1) K by a closed-loop mechanical cooler.

Tab. 1. General specifications of SPOrt@ISS radiometer

Frequency	22, 32, 60, 90 GHz
Angular resolution	HPBW ≈7°
Pixel sensitivity (antenna temperature)	3.4-6.3 K
P(rms) sensitivity	<0.3 K
Sky coverage	>80% (every 70 days)
Lifetime	1.5 year (extendible to 3)
Mass/size	62 Kg/450 mm x 450 mm x 1170 mm

The SPOrt receivers provide the Stokes parameters Q and U, representing the linear polarization, by analog correlators (Fig. 1). Tj10.0183 0 0 1

