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The Sky Polarisation Observatory (SPOrt) Program

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Abstract. The goal of the Sky Polarisation Observatory (SPOrt) Program is the measurement of the sky linearly polarised emission in the 22-90 GHz frequency range from the International Space Station (2003-2004). The instrument configuration together with most relevant ground support activities are presented. In particular, the development of hardware solutions for high sensitive polarimetric measurements has been addressed by the SPOrt team to match the experiment requirements.

1. Introduction

Most cosmological models predict that the Cosmic Microwave Background (CMB) is linearly polarized. By combining anisotropy and polarization data it will be possible to solve the residual degeneracy among cosmological parameters and, possibly, to distinguish between scalar and tensor contributions (Zaldarriaga, Spergel, & Seljak 1997). However, polarization yields a signal hardly approaching 10% of anisotropy, depending on the angular scale and on the detailed model. Hence, so far, only upper limits on polarization have been found (see Fabbri et al 1999).

Among the experiments planned to attempt the first measurement (for a list see Staggs, Gundersen, & Church 1999), SPOrt[1] is the only space program dedicated to study the polarisation in the microwave domain (Cortiglioni et al. 1999). Since we feel that only a dedicated instrument may face a so challenging measurement, SPOrt has been designed to minimize systematics as well as instrumental polarisation. In the light of this, the most critical components of the SPOrt radio–polarimeters are realised customly.

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[1] http://sport.tesre.bo.cnr.it

2. The SPOrt Experiment

SPOrt (Cortiglioni et al. 1999) will survey the linearly polarised emission of the microwave sky between 22 and 90 GHz at large angular scale (HPBW = 7°). The experiment is scheduled to be flown on board International Space Station (ISS) and it will scan more than 80% of the sky in 1.5 Yr lifetime. SPOrt consists of 4 polarimeters at 22, 32, 60 and 90 GHz fed by corrugated horns directly measuring the two Stokes parameters Q and U. Other relevant features of SPOrt are: BW=10%, average pixel sensitivity (50% observing efficiency) of 5 μK (full sky ~ 0.2 μK).

The leading effort of the SPOrt team is to build an instrument dedicated to polarisation measurements whose components are designed to minimize systematics. The main choices operated to obtain this goal are listed below:

- *Correlation receivers* to reduce gain fluctuation effects ($1/f$ noise). The radiometer equation is (Wollack & Pospieszalski 1998)

$$\Delta T_{\rm rms} = T_{\rm sys}\sqrt{\frac{k^2}{\Delta\nu\,\tau} + \left(\frac{T_{\rm offset}}{T_{\rm sys}}\right)^2\left(\frac{\Delta G}{G}\right)^2} \qquad (1)$$

  where $T_{\rm sys}$ and $T_{\rm offset}$ are the system temperature and the offset equivalent temperature, respectively, G is the radiometer gain, τ is the integration time, $\Delta\nu$ is the frequency bandwidth and the constant k depends on the radiometer type. Here the first term represents the white noise of an ideal radiometer, the second one is the noise generated by gain instabilities and it is driven by the offset. While a direct receiver has $T_{\rm offset} = T_{\rm sys}$, a correlation one has $T_{\rm offset} \ll T_{\rm sys}$, providing stability on longer time scales.

- *Correlation* of the left and right–hand circularly polarised components E_L and E_R. The combination of polariser and OMT allows to extract E_L and E_R, whose correlation simultaneously provides both Q and U:

$$Q \propto E_L E_R \cos(\delta) \qquad (2)$$
$$U \propto E_L E_R \sin(\delta) \qquad (3)$$

  where δ is the mean phase difference between E_L and E_R. This allows a better time efficiency with respect to polarimeters correlating the two linearly polarised components, which require two separated measurements for Q and U.

- *Low contamination* from the unpolarised component of the radiation. The polarisation degree of the CMB is so low (10^{-6}–10^{-7}) that even a small (unwanted) instrumental correlation of the unpolarised components contamines the signal (Carretti et al. 2000). Many efforts have been spent to improve the OMT insulation (< -40 dB over the band) as well as the correlation unit. The latter is based on a waveguide Hybrid Phase Discriminator (HPD), whose rejection of the unpolarised component is better than 30 dB over the band. In addition, a lock-in loop allows to further improve the total rejection of the unpolarised signal.

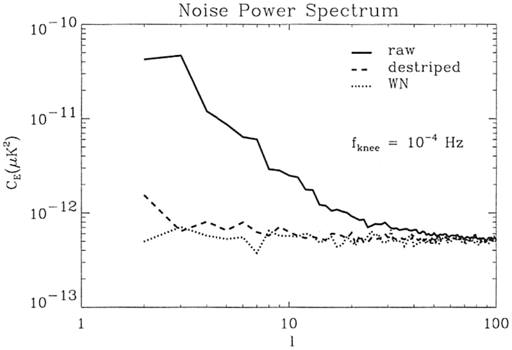

Figure 1. Angular power spectra (E mode) of noise maps obtained from simulations of the SPOrt experiment. The solid and dashed lines represent the power spectra obtained for $f_{\rm knee} = 10^{-4}$ Hz, before and after destriping, respectively. For comparison, the dotted line shows the power spectrum without $1/f$ noise ($f_{\rm knee} = 0$).

Because of the ISS constraints, the scanning strategy of SPOrt is based on the ISS orbit, which provides a modulation of the signal on orbit time scale (90 min). Signal modulation allows to recover the $1/f$ noise by means of destriping techniques, which work when the knee frequency $f_{\rm knee}$ of the instrument is lower than the modulation frequency. The high rejection of the unpolarised component allows SPOrt to have an offset $T_{\rm offset} \sim 300$ mK that, combined with the gain stability features of front end amplifiers by TRW (Gaier et al. 1996), provides $f_{\rm knee} < 10^{-4}$ Hz, compatible with the SPOrt $f_{\rm orbit} = 2 \times 10^{-4}$ Hz.

An iterative destriping technique working simultaneously on both Q and U was developed by Orsini et al. (2000), based on the subtraction, orbit by orbit, of offset fluctuations estimated from raw data. The efficiency of this method is shown in Figure 1, where the angular power spectra of noise maps before and after destriping are compared in the case of a simulated experiment with $f_{\rm knee} = 10^{-4}$ Hz: the destriping is able to subtract the $1/f$ effects resulting in noise maps affected only by white noise. In summary, the SPOrt overall strategy is based on: design efficiency, custom components and off–line processing. This should provide data free of gain fluctuation effects.

3. Scientific Goals

So far, the polarised sky has not been well investigated in the radio and microwave domain. Up to now, only data at frequencies below $\simeq$ 3 GHz are available and their coverage is either limited to narrow strips around the Galactic plane or undersampled (see Uyaniker et al. 1999 and references therein). The aim of SPOrt is to extend polarisation measurements to higher frequencies, providing Q and U maps of 80% of the sky with unprecedent sensitivity.

The most challenging goal of SPOrt is to attempt the detection of the CMB linear polarisation. At 7° angular scale the mean CMB polarisation level $P_{\rm rms} = (\langle Q\rangle^2 + \langle U\rangle^2)^{1/2}$ depends mostly on τ, the optical depth of the Universe after the primeveal plasma has recombined (see Figure 2). The SPOrt sensitivity on $P_{\rm rms}$ ($\sigma = 0.2\ \mu$K, see also Tucci et al. 2000b) will allow a polarisation detection, at 1(2)–sigma confidence level, if $\tau > 0.06\,(0.12)$. Such values of

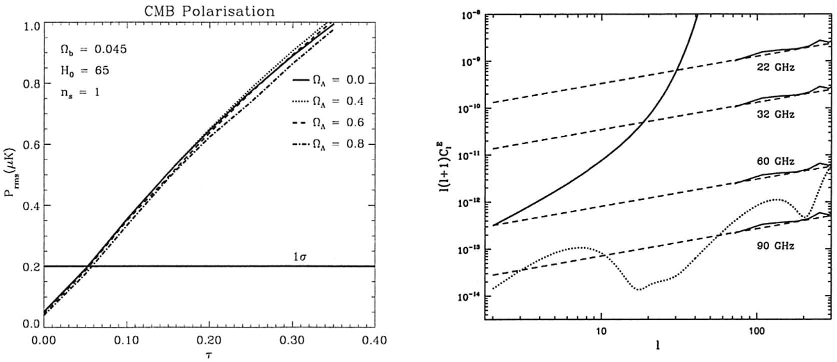

Figure 2. The $P_{\rm rms}$ for some cosmological models as well as the SPOrt sensitivity (left). Expected synchrotron power spectra and the SPOrt sensitivity on C_E (solid line). The power spectrum of a SCDM model with $\tau = 0.2$ is also shown (right).

τ are fully consistent with recent anisotropy measures. Moreover, the SPOrt maps will allow us to improve the knowledge of the Galactic emission, which represents also a foreground in CMB observations. The Galactic synchrotron, in fact, dominates at the lowest frequencies of SPOrt (22 and 32 GHz), and the knowledge of its frequency and angular behaviours is fundamental to address CMB measures. In Figure 2 the expected Galactic–synchrotron power spectrum (Tucci et al. 2000a) together with the SPOrt sensitivity are plotted. As one can see, SPOrt will be able to build synchrotron maps at 22 and 32 GHz. Last but not least, SPOrt can provide a check on recent estimates of the spinning dust grain emission (Lazarian & Draine 2000) which may play a meaningful role in CMB measurements.

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