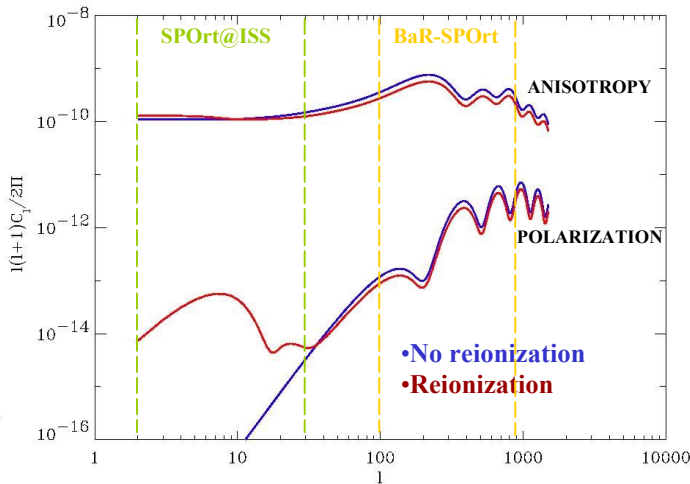


The SPORt Program

The last decade of the 20th century has seen great advances in observational cosmology due to the NASA-COBE space mission in the first place. More recently BOOMERanG and MAXIMA balloon experiments as well as DASI 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. This radiation, predicted in 1948 and discovered in 1965, has a black body spectrum measured now to a very high precision. A second 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

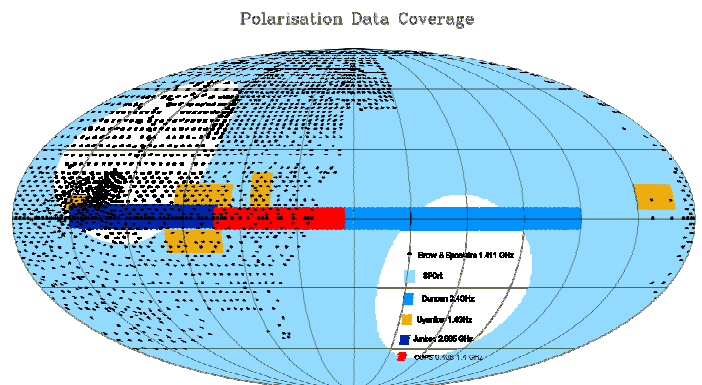
be the seeds of the present cosmological structures. The detailed structure of this spectrum allows to test different cosmological models and to increase the precision in the determination of the Universe parameters. A third feature of CMBR is that this radiation can be (linearly) polarized. However, 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. 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. The SPORt¹ (Sky Polarization Observatory) Program is facing the problem by preparing two experiments: **SPOrt@ISS** and **BaR-SPOrt**. 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. 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. 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 μ K 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.



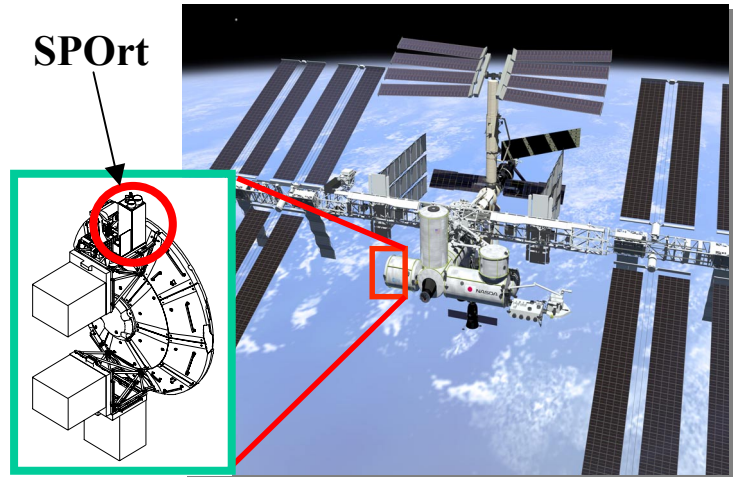
¹ <http://sport.tesre.bo.cnr.it/>

SPOrt@ISS

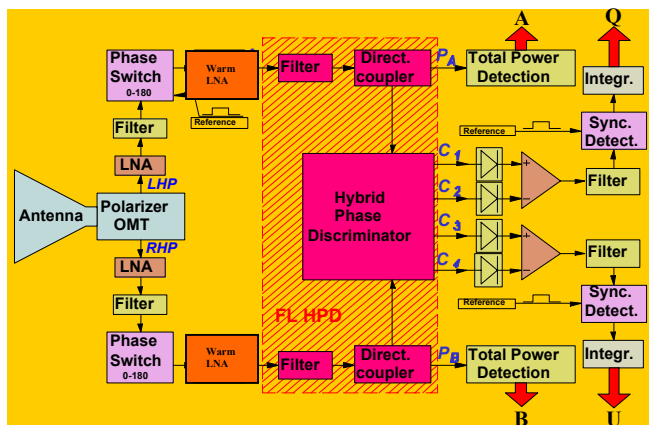
The International Space Station (ISS) is the largest manned structure to be built in space. Five space agencies (USA, Russia, Canada, Japan and Europe) are contributing to the realization of this huge laboratory flying around the Earth for more than 10 years with a permanent crew. Its low polar orbit (350-450 km of altitude, 51.2° of inclination) with a 90 min. period will allow SPOrt@ISS to cover more than 80% of the sky every 70 days by observing the zenith (at least 7 complete surveys in 1.5 years of minimum lifetime). Beside pressurized laboratory, ISS will accommodate several external payloads aiming at both Earth and sky observations. In 1998 the European Space Agency selected 5 experiments (out of 21 proposed for space science, over a total of about 100) for the Early Utilization Phase starting in 2004. One of them, SPOrt@ISS, has been entirely designed and funded by the Italian Space Agency to be the first microwave scientific polarimeter for space astrophysics. The SPOrt@ISS goals are:

- the construction of very precise maps of the Galactic polarized emission at 22 and 32 GHz, where synchrotron dominates;
- the attempt to measure the large scale polarization of the Cosmic Microwave Background Radiation at 60 and 90 GHz, where the so called “cosmological window” (in the frequency-angular scale plane) should allow us to investigate the deep sky.

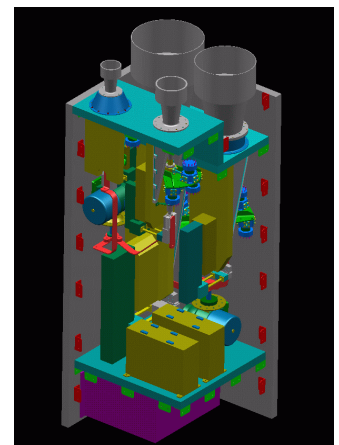
Due to the ISS constraints SPOrt shall use a 7° beam (HPBW) at all frequencies. However, degree angular scales bring the most important information on the optical depth at re-ionization epochs even though the expected polarization signal is lower. On the other hand, low signals require more sensitivity as well as long term stability and low systematics. SPOrt@ISS represents the synthesis between simplicity and a new receiver architecture applied to space microwave 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 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.

Frequency	22, 32, 60, 90 GHz
Angular resolution	HPBW =7°
Pixel sensitivity (antenna temperature)	3.4-6.3 μK
P(rms) sensitivity	<0.3 μK
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

