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OLIMPO: A few arcmin resolution survey of the sky at mm and sub-mm wavelengths

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Abstract. OLIMPO is a 2.6 meter on-axis millimeter-wave Cassegrain telescope, mounted on an attitude controlled stratospheric balloon payload. This telescope is designed to be flown with a > 10 days Long Duration CircumPolar flight. The system contains 4 arrays of bolometers in the wavelength bands centered at 150, 220, 350, 600 GHz. The instrument will be diffraction limited at 150 GHz (3.5 arcminutes FWHM). It is currently planned to have a test flight from Trapani in 2003/4.

Key words. Cosmology – Cosmic Microwave Background

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1. mm/sub-mm waves and cosmology

Mm and sub-mm waves represent the last portion of the electromagnetic spectrum

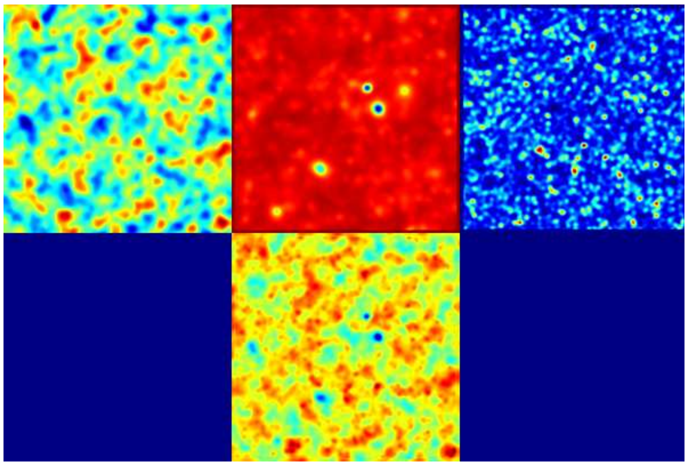

Fig. 1. Realistic simulation of the sky at 150 GHz. The top left panel is CMB anisotropy (from the best fit power spectrum of the BOOMERanG data); the center top panel is the signal from field SZ clusters ($\Omega_\Lambda = 0.7$); the top right panel is the signal from galaxies as extrapolated from the SCUBA survey. The bottom panel is the sky map deriving from the combination of the three signals. A multi band measurement is needed to separate the three contributions, taking advantage of the very different spectra.

where we do not have a good sky survey. The development of new detectors, like the extremely sensitive micromachined bolometers (Mauskopf et al. (1997)), and the availability of long duration balloon flights (Orr et al. (2002)) are slowly improving the situation. The highly successful BOOMERanG experiment (de Bernardis et al. (2000)) has provided deep maps of ~ 3 of the sky in the range 90 to 400 GHz, with a resolution of $\sim 12'$. Other balloon experiments, like Pronaos (see e.g. Lamarre et al. (1998)), have provided high angular resolution maps of smaller selected targets. The BLAST experiment will cover the spectral range 600-3000 GHz with arcmin resolution (Devlin et al. (2001)). The OLIMPO payolad, described here, will cover the range 150-600 GHz with $\sim 4'$ resolution, mapping significant parts of the sky. All these searches are preliminary and complementary to the surveys of the Herschel, Planck and SIRTF satellites, coming later this decade.

The science drivers for these mm and sub-mm continuum surveys are compelling for cosmology, for the interstellar medium and for star formation. Here we will focus on the cosmology side.

In Fig.1 we show a realistic simulation of a high Galactic latitude patch of the sky at 150 GHz, as decomposed in different components. It is evident the different contribution of external galaxies (including AGNs), clusters of galaxies, and the CMB. Any experiment seriously attempting the detection of these components has to be multi-band (see e.g. Bouchet and Gispert (1999)).

• A survey of Clusters of Galaxies, visible via the Sunyaev-Zeldovich effect, can provide crucial information about the background cosmology and about the Hubble Constant (see e.g. Birkinshaw (1999), Carlstrom et al. (2001)). Clusters can be seen against the CMB background at high redshift, much deeper than in the complementary optical and X-ray surveys, thus providing a unique tool to investigate the early evolution of structures. The OLIMPO bands are ideally suited to measure the Sunyaev-Zeldovich effect in clus-

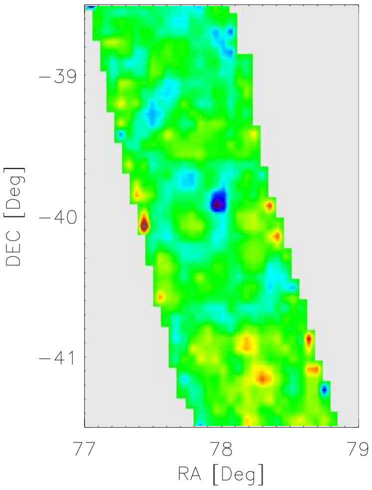

Fig. 2. Realistic simulation of OLIMPO observations of a rich cluster of galaxies at 150 GHz. We assumed scans at 1^o/s, amplitude of the scans 3^op-p, detector noise 150 $\mu K s^{1/2}$, 1/f noise knee 0.1 Hz, total observing time 4 hours, comptonization parameter for the cluster y=10^{-4}. The cluster is the dark spot at RA$\sim$ 79^o and dec$\sim$ -39.9^o. The other structures are due to residual CMB anisotropy. The data have been filtered so that signals at scales larger than 0.1^o have been heavily suppressed.

ters of galaxies and distinguish it from competing foregrounds. We plan to map about 40 clusters per flight, and combine these measurements with X-ray measurements to build a "Hubble diagram" for the determination of H_o. Deep surveys of SZ clusters can give independent estimates of Ω_Λ and Ω_m through the evaluation of clusters counts and the shape of the power spectrum (Refregier et al. (2000)) . In Fig.2 we show a realistic simulation of the observation of one cluster using the OLIMPO array at 150 GHz.

• CMB anisotropy at high multipoles ($\ell \gtrsim 600$) can be detected in the lower frequency bands of OLIMPO, providing estimates of the dark matter density in the Universe through the measurement of the damping tail of the power spectrum (**?**).

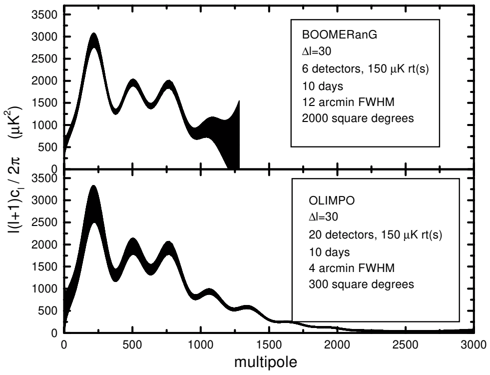

Fig. 3. Comparison of OLIMPO and BOOMERanG capabilities in the measurement of the power spectrum of the CMB. OLIMPO can accurately measure the damping tail at high multipoles.

Taking advantage of its high angular resolution, and concentrating on a limited area of the sky, OLIMPO will be able to measure the angular power spectrum of the CMB up to multipoles $\ell \sim 3000$, significantly higher than BOOMERanG, MAP and Planck. In Fig.3 we compare the projected sensitivity of OLIMPO to the sensitivity of BOOMERanG. This measurement will complement those of the low-frequency ($\sim 30-90$ GHz) ground based interferometers. Due to the higher frequency this measurement will provide a mandatory cross-check for potential foregrounds. Also, the high multipoles tail of the power spectrum of the sky includes contributions from any point sources population, like SZ clusters or early galaxies. Only multiband observations can discriminate between them.

• The Extragalactic Far Infrared Background has been measured by the COBE satellite (Puget et al. (1996)) and is believed to result from an early generation of Galaxies, still unresolved. Resolving the FIR background and studying the unresolved component is important in order to investigate the cosmic "middle ages" at $z \sim 1-10$, where the first light shines again in the Universe. High Star Formation Rate is expected at these redshifts (Madau

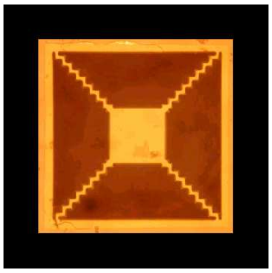

Fig. 4. Bolometers technology development: a suspended island in a 1 μm thick silicon nitride membrane. The side is 150 μm. The standoffs are 10 μm wide, and the bolometer's thermistor is glued to the island. EM signals arrive to the thermistor from a bow-tie antenna through planar transmission lines (not shown)

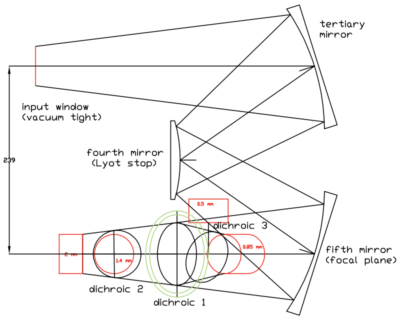

Fig. 5. The reimaging optics, the dichroics and the bolometer arrays are all contained inside a large Helium dewar.

(1999)). Cosmic star formation history can thus be investigated in a way completely orthogonal to the deep visible and NIR surveys; the very significant (negative) K-correction present at these wavelengths makes sub-mm observations quite sensitive (Hughes et al. (2002)).

2. OLIMPO: the payload

OLIMPO is implementing a number of advanced technical solutions.

The Cardiff group is in charge of developing the four arrays of bolometers and the dichroics for the multiband focal plane. These detectors are an evolution of the highly successful devices used in the BOOMERanG and Planck-HFI instruments (Mauskopf et al. (1997)). A micromachined array element is visible in Fig. 4. We will mount 4 arrays at 2.0, 1.4, 0.85, 0.50 mm of central wavelength, with 19, 37, 37, 37 detectors respectively. Each array will fill the optically correct area of the focal plane (about 0.5^o in diameter projected in the sky).

The cryogenic reimaging optics is being developed in Rome (see Fig. 5). It is mounted in the experiment section of the cryostat, at 2K, while the bolometers are cooled at 0.3K. Extensive baffling and a cold Lyot stop reduce significantly straylight and sidelobes. The bolometer arrays and the reimaging optics will be mounted in a long duration cryostat similar to the BOOMERanG one (Masi et al. (1998), Masi et al. (1999)).

The telescope is also being developed in Rome. It is a classical Cassegrain with a 2.6m aluminum primary (De Petris et al. (1996)). The secondary mirror is suspended by means of kevlar cords. Sky scans are obtained by slowly scanning the primary mirror in the cross-elevation direction. The chopper design is similar to the ones in de Bernardis et al. (1989) and Mainella et al. (1996). Up to 3^o wide, 1^o/s cross-elevation scans are possible with this system.

The rest of the payload (Data acquisition, Attitude control system, Telemetry, Thermal Shields and Housekeeping) is similar to the BOOMERanG experiment (Piacentini et al. (2002) Crill et al. (2002)). In Fig. 6 we sketch the full OLIMPO payload, currently under design. The Attitude Control System is derived from the BOOMERanG and completed with day and night-time attitude sensors: laser gyroscopes, sun sensors, star camera.

The test flight will be a trans-mediterranean flight from Sicily to Spain, to be done in 2003/4 as a joint venture between the ASI and the NSBF.

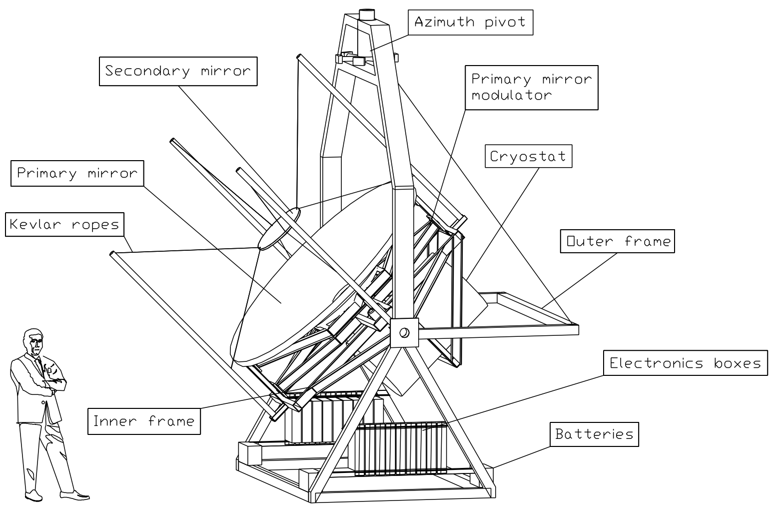

Fig. 6. The OLIMPO payload with all shields removed

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References

Bouchet, F. & Gispert, R. 1999, New Astron., 4, 443
Birkinshaw, M. 1999, Phys. Rep., 310, 97
Carlstrom, J.E. et al. 2001, astro-ph/0103480
Crill, B.P. et al. 2002, ApJ, to be submitted
de Bernardis, P., et al. 2000, Nature, 404, 955
de Bernardis, P. et al. 1989, Infrared Phys. 29, 1005
De Petris, M. et al. 1989, Appl. Optics, 28, 1785D,
Devlin, M.J. et al. 2001, astro-ph/0012327
Hughes, D.H. et al. 2002, astro-ph/0111547.
Lamarre, J.M. et al. 1998, ApJ, 507, L5
Madau P. 2000, in Phys. Scripta T85, Proceed. of the Nobel Symposium 109, Particle Physics and the Universe, ed. Bergstrom, Fransson & Carlson
Mainella, G. et al. 1996, Appl. Optics, 35, 2246
Masi, S. et al. 1999, Cryogenics, 39, 217
Masi, S. et al. 1998, Cryogenics, 38, 319
Mauskopf, P., et al. 1997, Appl. Optics 36, 765
Orr, G.D., Ball, D.R.J., & Smith, S.Jr. 2002, in AIP Conf. Ser. 609, Astrophysical Polarized Backgrounds, ed. S. Cecchini, S. Cortiglioni, R. Sault & C. Sbarra, 235
Piacentini, F., et al. 2002, ApJS, 138, 315
Puget, J.L. et al. 1996, A&A 308, L5
Refregier, A. et al. 2000, Phys. Rev. D, 61, 123001