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Millimetric observations with a high-altitude 2.6 m ground-based telescope(*)

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Summary. — High atmospheric performances are necessary to ensure efficient sub/millimetre cosmological observations from ground. Low atmospheric components fluctuations along the line of sight are a must for best detector applications. Such site constraints are attained only at in specific places around the world: high-altitude observatories or, equivalently, polar regions. We are currently involved in cosmological observations with the MITO project from an Alpine ground station which satisfies such requirements: the Testa Grigia mountain at 3500 m a.s.l., AO—Italy. The Chacaltaya laboratory at 5200 m a.s.l. could also be an appropriate mm-site. One of the goals of MITO is the multifrequency observation of nearby rich clusters of galaxies for measuring the Sunyaev-Zel'dovich effect. Combined S-Z and X-ray measurements yield the Hubble constant and other cosmological information. A dedicated instrument has been designed to minimize spurious contaminations on the signals. The telescope is a 2.6 m Cassegrain with a wobbling subreflector and a 4-band single pixel photometer installed at the focal plane. The bolometric detectors are cooled down to 300 mK by a double stage He3-He4 fridge.

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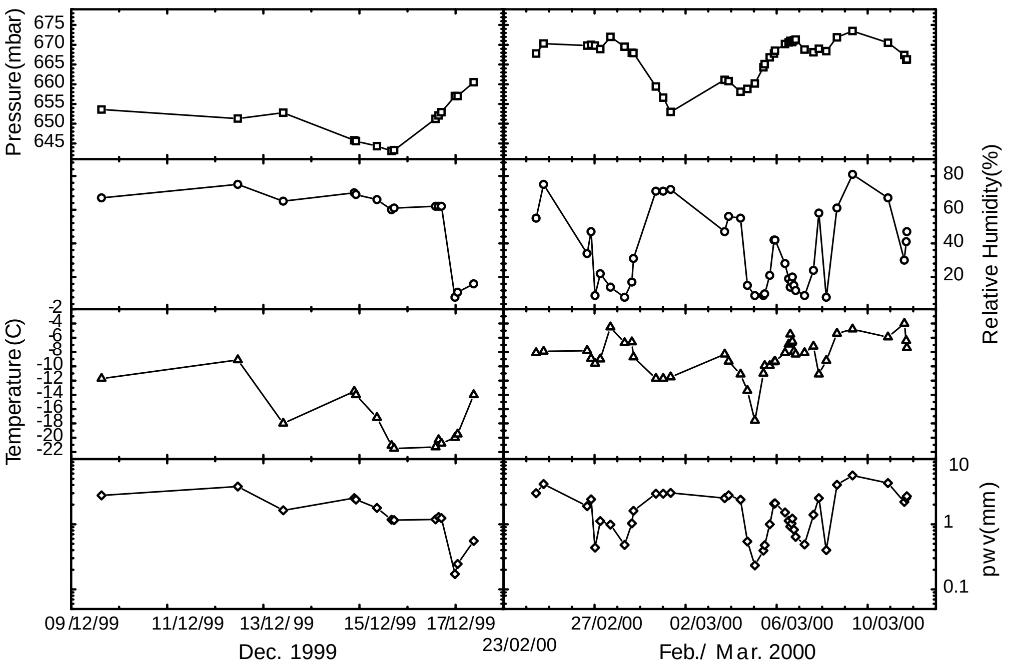

Fig. 1. – Meteorological data (pressure, relative humidity, temperature and pwv) during two 1999-2000 winter campaigns at MITO.

1. – Why high-altitude site

Sky millimetre observations from ground are strongly affected by emission and absorption by the main atmospheric constituents, such as water vapor, oxygen and ozone. The final effect is twofold: reduced total transmission and level fluctuations. Lower precipitable water vapor content (pwv), *i.e.* the amount of H_2O along the telescope line of sight, means higher transmission in the *mm-windows*. This requirement is only satisfied at dry and cold sites. The station on the Testa Grigia mountain in the Italian Alps (Breuil-Cervinia Val d'Aosta) at 3500 m a.s.l. is really competitive with other mm-observatories around the world. In fig. 1 we show meteorological data collected during two 1999/2000 winter observational campaigns when the pwv was lower than 1 mm for several nights.

These performances should be compared with data reported in table I for a few of the best mm-sites at least for 25% of the time [1].

TABLE I. – *Precipitable water vapor content values during the best quartile for several mm-sites.*

Site	25% Time	pwv (mm)
Dome Concordia - Antarctica	Summer	0.38
South Pole - Antarctica	Winter	0.19
Mauna Kea - Hawaii	Winter	1.05
Atacama - Chile	Winter	0.68

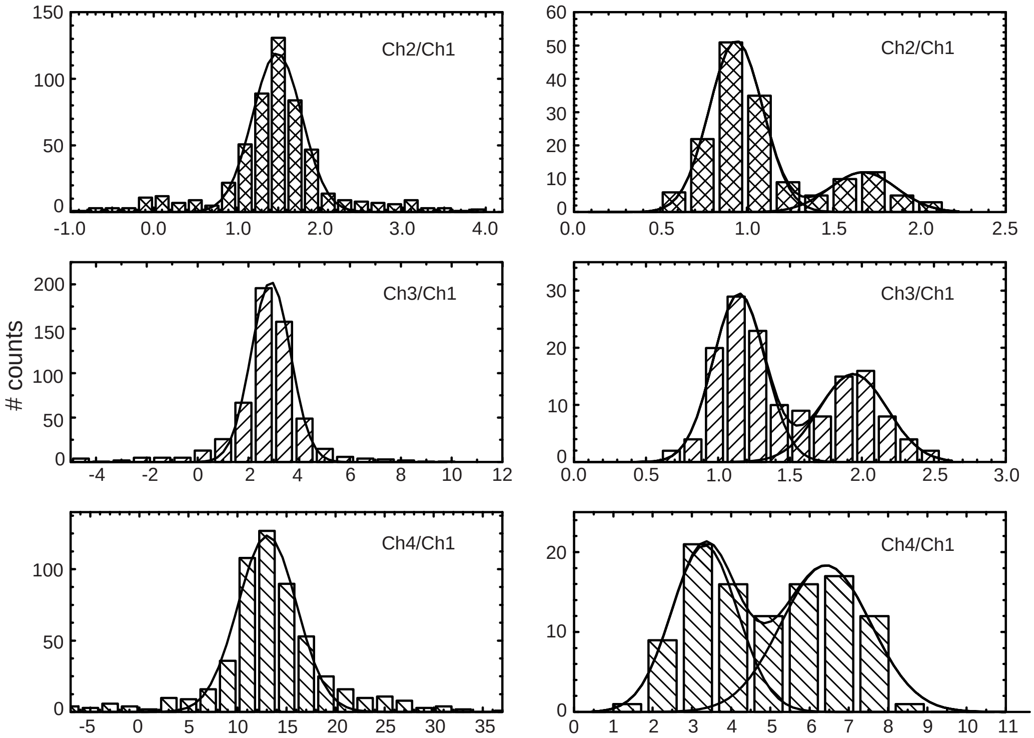

Fig. 2. – Channel ratios comparison for single (left panels) and bimodal (right panels) distribution with perturbations at different layers.

The atmospheric emission, even 5–6 orders of magnitude brighter than our cosmological targets, is minimized by a differential angular modulation also able to limit its fluctuations. A check for the Gaussian distribution of the noise is mandatory for estimating the necessary integration time on source.

A multifrequency observation allows the monitoring of atmospheric noise using spectral correlation between different bands. Optimum removal is obtained if the correlation is high and constant in time during the scan. Unacceptable conditions are when channel ratios are not unique but multimodal distribution is evident. In this case inefficient decorrelation methods are applied. For example in fig. 2 two distinct atmospheric conditions are shown: a bimodal distribution is evident when constituent perturbations are present in two different layers.

2. – Cosmological targets

The millimetre spectral band is ideal for observing Cosmic Microwave Background Radiation by matching its maximum emission. CMB anisotropies have been mapped at large angular scales (10 degrees) by the COBE satellite [2] and, recently, by the BOOMERanG and MAXIMA balloon-borne experiments [3, 4] with a higher angular resolution of the order of 10 arcminutes.

For a ground-based observatory we have highlighted spatially located secondary anisotropies, known as Sunyaev Zel'dovich Effect (SZE), present in clusters of galaxies [5]. As

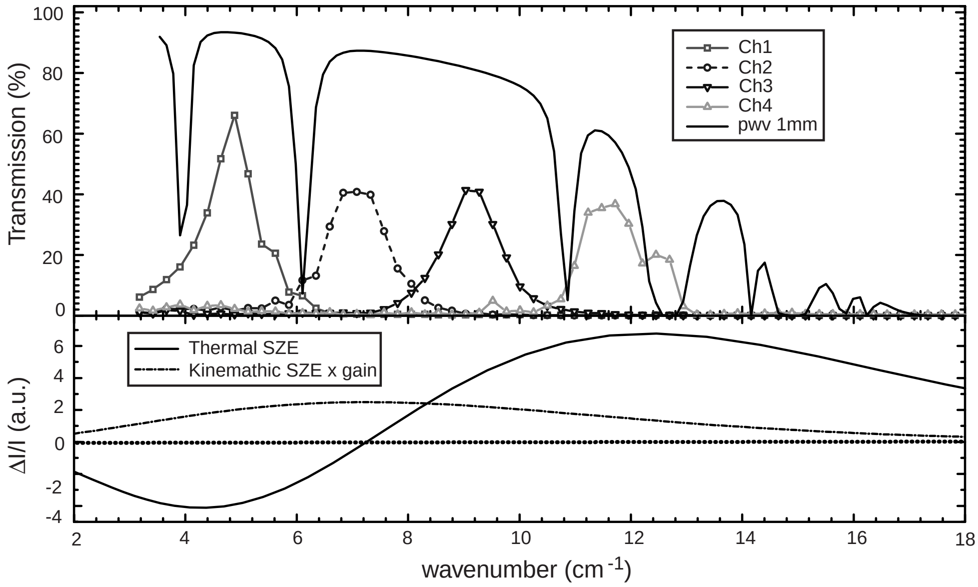

Fig. 3. – Transmission of the 4 channel photometer compared with an atmospheric spectra estimated for 1 mm of pwv (upper panel). SZE components: thermal = continuous line, kinematic = dot-dashed line, unperturbed spectra = dotted line (lower panel).

the first step we have selected large clusters (diameter $\geq$ 5 arcminutes), *i.e.* nearby sources. High-accuracy photometry of mm-sources (HII regions, radio sources, ..) is a second observational target as well as re-observation of "bumps" detected by balloon-borne experiments. Polarimetry of mm-sources and the search for CMB polarization will also be carried out in the future [6].

3. – MITO **instrument**

A 2.6 m in diameter telescope has been optimized for mm differential sky observation [7]. An aplanatic Cassegrain solution is derived by the requirements of diffraction-limited performances at 350 microns with a wobbling subreflector and compactness of the whole telescope. A spatial modulation ensures an efficient foreground removal and so a modulated signal is efficiently extracted from the noise by a lock-in technique. Several drawbacks should be considered. Spillover problems are minimized by undersizing primary mirror pupil. The varying telescope emission due to thermal gradients over the mirrors is controlled by large pupil overlapping during the modulation and by using high-conductivity metal mirrors for fast thermalization. Microphonics induced by the subreflector wobbling are nulled by tuning the electromechanical system [8].

Several scan waveforms are obtained by a computer-controlled wobbling subreflector: 2 or 3 fields, linear and sinusoidal. The Narcissus effect is reduced by a fixed conical mirror on the subreflector and baffles on the primary hole [9].

An altazimuthal mount allows for maintaining the modulation axis parallel to the horizon for every position in the sky. The derived reference beams rotation has to be

TABLE II. – *Spectral performances of 4-channel photometer.*

	Ch1	Ch2	Ch3	Ch4
wavelength([a]) (μm)	2000	1430	1110	895
frequency([a])(GHz)	150	209	270	335
wavenumber([a]) (cm^{-1})	5.0	6.9	9.0	11.2
$h\nu/KT_{\rm CBR}$([a])	2.64	3.69	4.75	5.89
bandwidth (% FWHM)	21	14	12	10
noise at 3 Hz (mK s$^{1/2}$)	1.20	1.13	0.89	2.61
optical responsivity (μK/nV)	430	370	400	345

([a]) Effective values for a flat emission source.

taken into account in the data reduction.

In order to disentangle the SZE from spurious contaminating sources, we have developed a 4-channel photometer centered at peak wavelengths of 2.1 mm, 1.4 mm, 1.1 mm and 850 microns. In table II we list the photometer spectral characteristics.

The spectral bands definition is conditioned by the available atmospheric windows at mm wavelengths and the cosmological target emission. In fig. 3 we can see the matching of the 4 channels with the atmospheric bands and the choice of exploring an SZE in the negative, null and positive emission.

A double-stage fridge cools down 4 composite NTD Ge bolometers to 290 mK [10].

4. – Recent results

As a first step of the observational programme at MITO we selected several rich nearby clusters of galaxies. During the latest campaigns we have performed several drift scans on A1656 (Coma cluster) and a thermal SZE of the order of 500 μK was detected. The data analyses with a decorrelation method using spatial and spectral information as well as the cosmological results are being published elsewhere.

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