# Archeops: a ballon experiment for measuring the Cosmic Microwave Background anisotropies

A. Benoît[1], and the Archeops Collaboration[2]

[1]*Centre de Recherches sur les Très Basses Temperatures, CNRS, 25 avenue des martyrs, BP166, F–38042 Grenoble Cedex 9, France*

[2]*includes scientists from Caltech (USA), Cardiff Univ., CESR (Toulouse), CSNSM (Orsay), CRTBT (Grenoble), IAS (Orsay), IAP (Paris), IROE (Firenze, Italy), ISN (Grenoble), JPL (USA), LAL (Orsay), LAOG (Grenoble), Landau Institute (Russia), La Sapienza Univ. (Roma, Italy), LAOMP (Toulouse), Maynooth Univ. (Ireland), Minnesota Univ. (USA), PCC (Paris), SPP (Saclay)*

## ABSTRACT

The Archeops experiment has measured the anisotropies of the cosmic microwave background at angular scales from 10 arcminutes up to 20 degrees. For this purpose we use a 1.5 m telescope pointing at 41 degree elevation around its vertical axis on board of a stratospheric gondola. By spinning the gondola, a large fraction of the sky is covered when the Earth rotation makes the swept circle drift across the celestial sphere. This is only possible if the observations are done during the Arctic night when the Sun does not disturb the measurements. Another condition is to have very sensitive and fast detectors in the millimeter and submillimeter domain (high frequency radio domain of a few hundred GigaHertz), where the 3 Kelvin radiation dominates the sky emission. This is achieved by cooling the bolometers with a dilution refrigerator, at a temperature of 0.1 Kelvin. The experiment has been launched four times by the CNES in the Swedish base of Esrange, near Kiruna. The two main flights ended in Russia with a landing in Siberia, allowing 19 h of flight at ceiling for the last one. The control of the experiment was done with satellite communication and the data was stored onboard. This experiment results from an international collaboration including USA (detectors and mirror), UK (cold optics), Italy (gondola, pivot and star sensor) and France (cryogenics, electronics, instrument integration and operation). It is a precursor for the PLANCK satellite and the HFI instrument in many aspects: telescope, bolometers, cold optics, open cycle dilution refrigerator that provides the 0.1 K temperature, scanning strategy, and data processing.

## INTRODUCTION

The anisotropies of the cosmic microwave background (CMB) have now been measured with various ground-based, balloon and satellite–borne instruments (*e.g.* Tegmark et al. 1996, de Bernardis et al. 2000, Netterfield et al. 2002, Hanany et al. 2000, Lee et al. 2001, Pryke et al. 2001, Sievers et al. 2002, Rubiño-Martin et al. 2002). One limitation of these measurements is the finite sampling effect on the celestial sphere called cosmic variance (see *e.g.* Knox, 1997), a fundamental source of noise even in the presence of perfect detectors: the anisotropy power spectrum noise to be measured is obtained through a finite number of realisations, especially at low multipole $\ell$ in a spherical harmonic decomposition. The only way to circumvent this variance is to observe a large fraction of the sky. This is the main aim of the ARCHEOPS balloon–borne instrument.

## INSTRUMENT DESIGN AND RESULTS

The purpose of the experiment is thus to measure the angular power spectrum on a broad range of $\ell$ multipoles, from COBE scales to degree–scale experiments. It leads to the design of the following instrument.

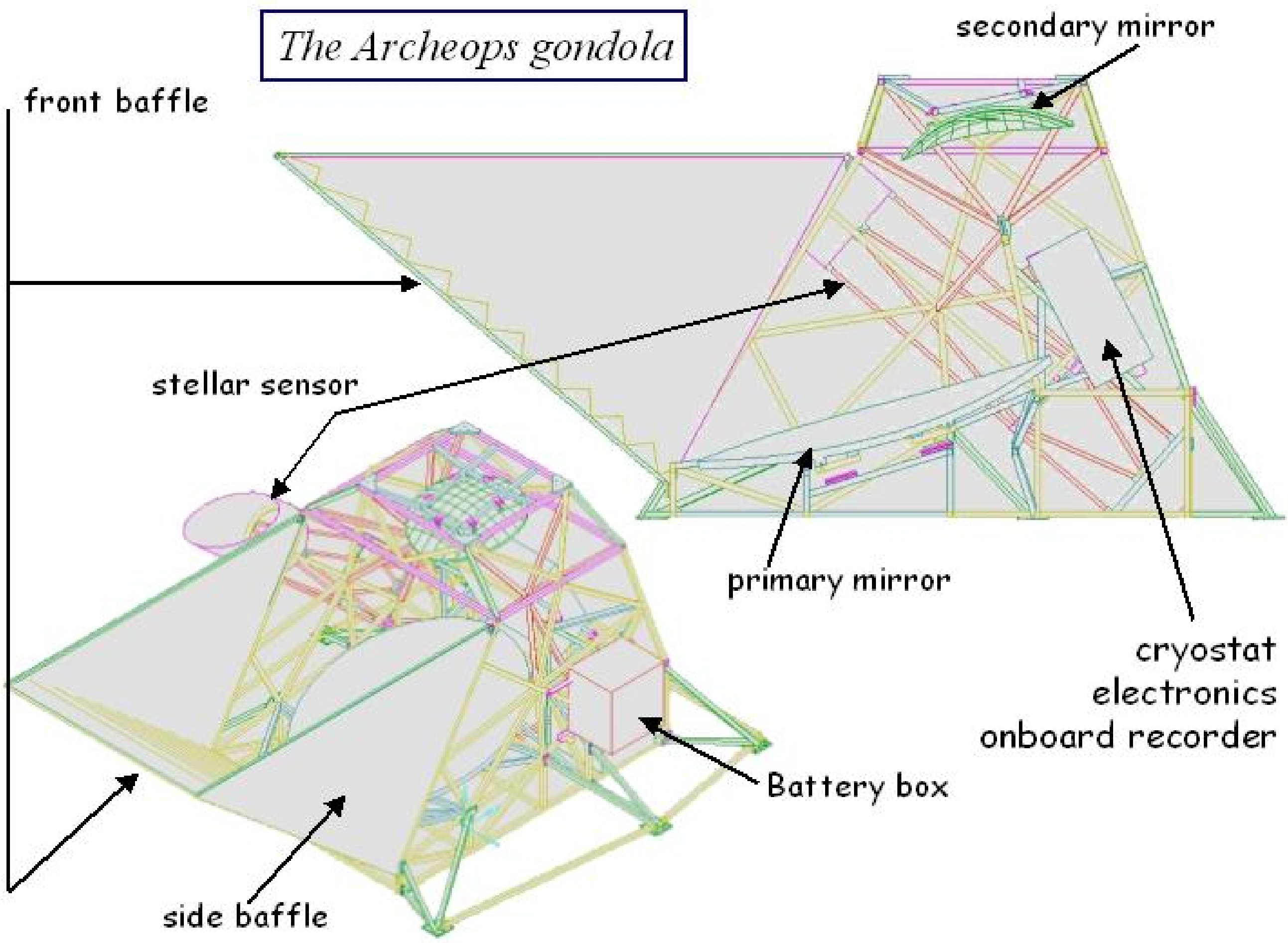


Fig. 1. Schematic views of the ARCHEOPS gondola.

The sky coverage is achieved by spinning the payload ($\sim$ 2 rpm) so that the detectors scan the sky at a constant elevation of $\sim 41°$, the diurnal motion producing a map of a large annulus on the sky during a day–long flight. The angular resolution is achieved with a 1.5 meter aperture off-axis telescope. Sidelobe rejection is done at the level of the optical horns which define the effective aperture and are in direct sight of the secondary mirror without any Lyot stop. The sensitivity, redundancy and checks for systematic effects are obtained with typically 8 bolometers at 143 GHz, 8 at 217 GHz, 6 at 353 GHz, and 2 at 545 GHz. The CMB signal is recorded by the 143 and 217 GHz detectors while atmospheric and interstellar dust emission are monitored with the 353 and 545 GHz detectors. An angular resolution of typically 10 arcminutes, required for the high $\ell$ modes, means fast bolometers. A time constant $\tau$ of less than few milliseconds (10 arcminutes are spanned in 18 milliseconds) is therefore needed. Spider-web bolometers at 100 mK have been developped (Bock, 1996) that meet these criteria. With a rotating gondola, the Sun above the horizon produces a dominant parasitic signal. The optimal way of avoiding it, while having the longest integration time, is by having a balloon flight with as much as 24 hour night time during the Arctic Winter from the Swedish Esrange Station (near Kiruna at 68 deg. latitude North) operated by the French Centre National d'Etudes Spatiales (CNES) and the Swedish Space Corporation. Additional information and updates may be found at our web–site[1]. A drawing of the gondola and its main parts is shown in Fig. 1. The total weight of the gondola is less than 500 kg and balloon volumes are from 400,000 to 1 million $m^3$.

Benoît et al. (2003a) and (2003b) show the results of a first reduction of the data, which are given elsewhere in this conference. As well as having a large scientific impact, ARCHEOPS has also provided

[1] http://www.archeops.org

validation of key technological issues for PLANCK – HFI .

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