Cosmologists Increase our Understanding of the Birth of the Universe

A French-led international consortium of cosmologists has mapped the remnant radiation from the birth of the Universe over the largest area of the sky to date with the most sensitive detectors. The team, headed by Alain Benoît of the Center for Very Low Temperature Research (CRTBT) in Grenoble, France, is able for the first time to directly tie together earlier measurements by NASA's COBE satellite to more recent observations. The results give some of the most precise measurement ever of the primeval fluctuations, demonstrating that space is flat.

The ARCHEOPS experiment, a sensitive instrument designed to see microwave radiation rather than optical light, was launched from north of the Arctic Circle on a scientific balloon to an altitude of 33 km, high above the Earth's atmosphere. The flight began February 7, 2002 from the balloon launch center in Kiruna, Sweden. It operated for almost a full day, piloted only by the winds, and traveled over Sweden, Finland and Russia, finally landing in Siberia after making the largest map ever that resolves the intricate patterns of structure in the relic radiation left over from the early Universe.

The results confirm that the universe is spatially flat. They are also in perfect agreement with the theory of primordial element production, yielding one of the most precise measurements of the normal matter content of our universe ever, and together with other data confirm that we do not yet recognize a large fraction of the mass and energy of the Universe.

The fossil radiation

The objective of ARCHEOPS is to observe the fossil radiation, known as the cosmic microwave background (CMB), left over from the Big Bang. This study is essential in the hunt for key parameters describing the Universe, such as the matter density (including the elusive dark matter), the Hubble constant (giving the expansion rate of space), and the age of the Universe.

The CMB radiation that we observe was emitted when the Universe was only 300,000 years old (today the age is about 10 billion years) and filled with a hot, homogeneous primeval plasma. At a temperature of several thousand degrees (similar to the temperature of the solar surface), this plasma emitted radiation with a wavelength of the order of 1 micron. During the subsequent expansion of space, the emitted radiation cooled until the present where we observe it at millimeter wavelengths. Since the primeval plasma was in thermal equilibrium, we thus observe a characteristic thermal spectrum with a temperature of about 3 Kelvin (3 degrees Celsius above absolute zero).

The ARCHEOPS results in the international setting

In 1965, two researchers at Bell Labs, Arno Penzias and Robert Wilson, first discovered the fossil radiation at centimeter wavelengths while searching for what was then an unknown source of radio noise. Their discovery was awarded the Nobel

Prize in 1978. The radiation intensity is extremely isotropic on the sky, so much so that it was not until 1992 that the COBE satellite first detected anisotropies of the order of 1 in 10,000 on scales larger than several degrees. Since then, an intense world-wide effort has been underway to measure the anisotropy on smaller scales. In 2000 the European-American BOOMERANG and MAXIMA collaborations and the American DASI collaboration accurately measured the anisotropy on these smaller scales and established several milestones of 20th century cosmology; most notably the fact that the Universe is spatially flat. With its high sensitivity, ARCHEOPS has confirmed these important results with unprecedented precision, as well as providing an important link between these smaller scale experiments and the ground-breaking results of NASA's COBE/DMR experiment. NASA's MAP satellite, launched in 2001, and the European Space Agency's Planck satellite, to be launched in 2007, will improve our understanding even more.

The ARCHEOPS Instrument

ARCHEOPS is designed to map a large fraction of the sky, which gives it unprecedented sensitivity on large angular scales. To achieve this, the 1.5 meter diameter telescope is suspended from a stratospheric balloon, pointing 45 degrees from vertical, and spun at about 2 revolutions per minute. With this scanning strategy, as much as one-third of the sky can be covered during a 12 hour flight. After a test flight from Sicily to Spain in 1999 (orchestrated by ASI, the Italian national space agency), the instrument was flown 3 times from Kiruna (Sweden) to Russia (orchestrated by the CNES, the French national space agency). Winter night flights from above the Artic Circle are necessary to avoid the combined effects of the Moon and Sun. The February 7, 2002 flight from Kiruna lasted for a total of 19 hours, providing 12 hours of scientific data at an altitude of 33 km.
At these wavelengths, from 400 microns to 2 mm, the most sensitive detectors are bolometers, which measure the temperature change of a crystal cooled to just one tenth of a degree above absolute zero (-273.15 C) by a sophisticated cooling system. These detectors are capable of measuring temperature differences on the sky of one part in 100000.

A Precursor to Planck

The ARCHEOPS experiment provided a crucial and very successful test of several state-of-the-art technologies that will be used on the ESA Planck mission. Planck, which is scheduled to be launched in 2007, is dedicated to making the definitive map of the faint structures imprinted in the CMB. The ARCHEOPS results released today are based on two detectors which viewed the sky for 12 hours. In contrast Planck, which is scheduled for launch in 2007, will view the sky for over a year with 94 detectors, thus obtaining thousands of times more data than ARCHEOPS.

An International Collaboration

The ARCHEOPS experiment in France represents a large collaboration involving many national research laboratories. The experimental team is an international collaboration lead by French CNRS (IN2P3 , INSU and SPM departments) and CEA (DAPNIA) laboratories. It has been supported by the Programme National de Cosmology, by the CNES (the French national space agency) and by the Région

Rhônes-Alpes. It brings together researchers from French, Italian, UK and US laboratories. The cooling system was developed at the Centre de Recherches Sur les Très Basses Températures (CRTBT/CNRS) in Grenoble. The balloon was launched and operated by the CNES (the French national space agency). The antenna feeds and filter elements were fabricated at Cardiff University in the UK with support from PPARC. The gondola, attitude control and stellar sensor were made at the University of Rome La Sapienza and IROE-CNR Florence, with funding from the Italian Space Agency (ASI). From the US, the ultra-sensitive detectors were developed by NASA/JPL in collaboration with the California Institute of Technology, and the telescope was developed by the University of Minnesota. The French groups led the system integration and calibration, launch campaigns as well as the data analysis. ARCHEOPS was made possible thanks to technology development for the High Frequency Instrument (HFI) onboard the European Space Agency's Planck mission to be launched in 2007.

WEB page

More information is available on the WEB page : **www.archeops.org**

Contacts

- *CNRS/SPM : Alain Benoît, Principal Investigator of the Experiment, Centre de Recherche sur les Très Basses Températures (CNRS-Grenoble).*
  Mél : benoit@grenoble.cnrs.fr
- *CNRS/IN2P3 : Yannick Giraud-Héraud, Laboratoire de physique corpusculaire et cosmologie (Collège de France, Université Paris7, CNRS – Paris)*
  Mél : giraud-heraud@cdf.in2p3.frq
- *CNRS/INSU : François-Xavier Désert, Laboratoire d'astrophysique de l'Observatoire des sciences de l'univers de Grenoble (CNRS, Université Grenoble 1)*
  Mél : Francois-Xavier.Desert@labs.polycnrs-gre.fr
- *CEA/Dapnia : Dominique Yvon, Dapnia/SPP*
  Mél : yvon@hep.saclay.cea.fr
- *California Institute of Technology : Andrew Lange*
  Mel : ael@astro.caltech.edu
- *University of Minnesota : Shaul Hanany*
  Mel : hanany@physics.umn.edu
- *University of Cardiff : Peter Ade*
  Mel : p.a.r.ade@qmw.ac.uk
- *University of Roma 1, La Sapienza : Paolo De Bernardis*
  Mel : debernardis@roma1.infn.it