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NEWSLETTER FOR THE

Canadian Antarctic Research Network

Inside

BOOMERANG: Exploring the Universe from the Antarctic Sky

Carrie MacTavish

In January of 2003, the BOOMERANG telescope completed a second successful Antarctic mission, probing the oldest light in the Universe, addressing the most fundamental of cosmological questions and testing the parameters of Big Bang Theory. The BOOMERANG group is an international collaboration of 35 scientists from Canada, Italy, the United States and the U.K. The Canadian contingent is from the University of Toronto (Departments of Physics and Astronomy) and the Canadian Institute for Theoretical Astrophysics. The latter played the lead role in data analysis, while the former took the lead on the telescope motion control and pointing instrumentation. Part of the team is shown in Figure 1. The results from this mission were published in 2006 (Jones and others, 2006; MacTavish and others, 2006; Masi and others, 2006; Montroy and others, 2006; Piacentini and others, 2006).

BOOMERANG is a balloon-borne, microwave telescope designed to measure the Cosmic Microwave Background (CMB). The CMB is one of the firm predictions of Big Bang theory and is a field of electromagnetic radiation that is cosmic in origin, that is originating from the Universe itself. It radiates in the microwave (0.3–630 GHz), with a near perfect black-body spectrum which peaks at 160.4 GHz, corresponding to a temperature of 2.725 K. The CMB covers the entire sky and appears as a background to all other objects, for instance stars, galaxies, etc. It was first detected in 1965 by Penzias and Wilson (1965) and has been measured since then by countless instruments with ever-increasing sensitivity.

In the most generic scenario, Big Bang theory predicts that the Universe is expanding and that it was hotter and denser in the past than it is now. When it was less than ~300,000 years old there was a period when the scattering rates of matter and radiation exceeded the expansion rate, resulting in near equilibrium conditions for the Universe's constituents. At some point after the first few hundred thousand years, the Universe expanded and cooled enough so that matter and radiation eventually decoupled. At this time, protons and electrons combined to form neutral hydrogen and the photons were allowed to travel freely throughout the Universe. The surface from which CMB photons last scattered is often referred to as the last scattering or decoupling surface. The CMB photons observed today offer a snapshot of the Universe in its infancy.

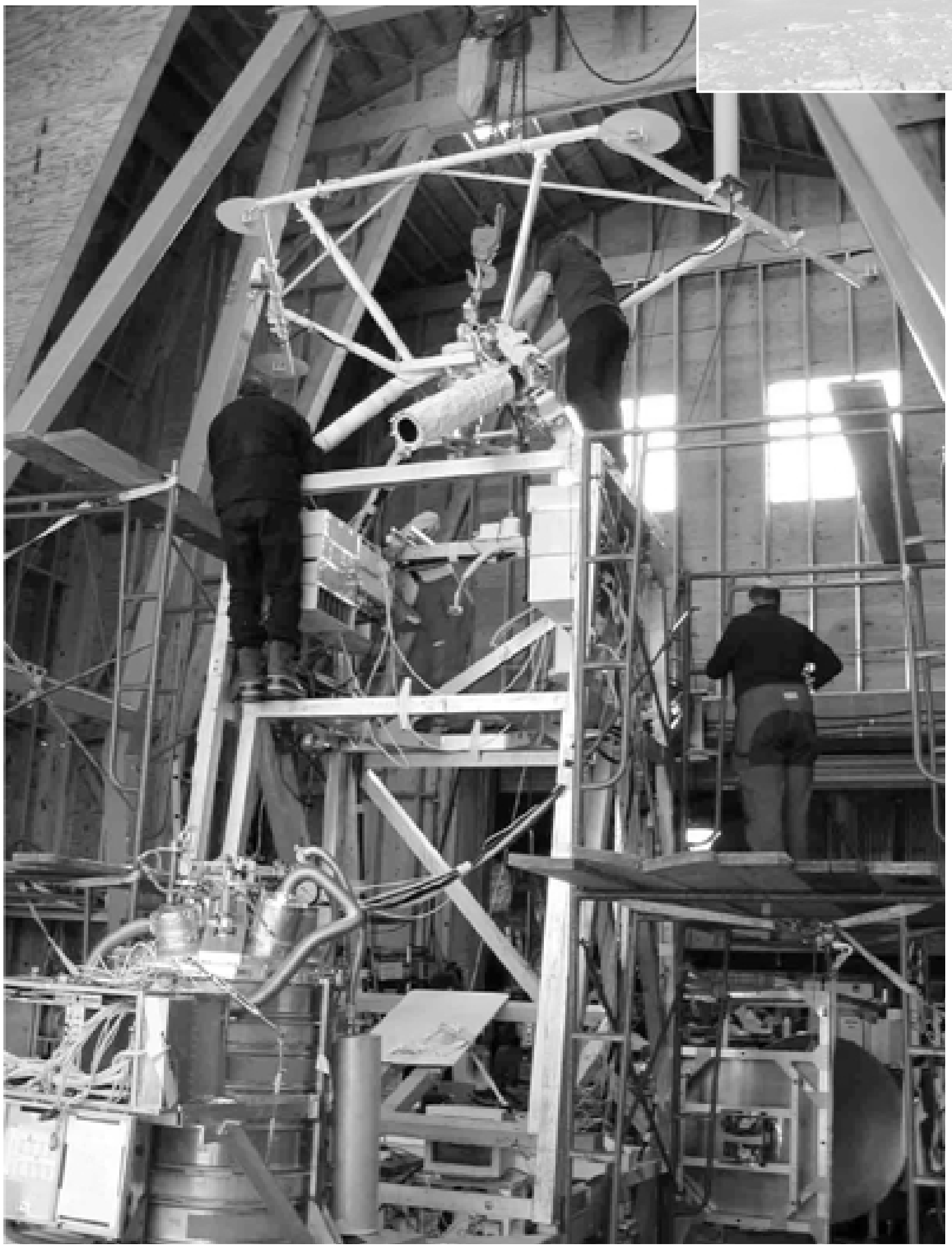

Figure 1 (above)
Part of the BOOMERANG collaboration (with penguin visitor) during pre-launch instrument integration.

Figure 2 (left)
Hard at work early in the Antarctic campaign.

Figure 3 (right)
Flight-ready payload.

While the CMB is extremely uniform, there are tiny fluctuations in its intensity and polarization. These trace tiny non-uniformities in the early Universe which grow into the large-scale structure observed in the sky today. The fluctuations in the photon density appear as

BOOMERANG measures light at 145 GHz, 245 GHz and 345 GHz. The instrument is mounted on a ~5 m tall aluminum frame or gondola and the entire flight-ready payload is ~1650 kg. The gondola has an inner frame which can be driven in elevation and an outer frame which scans in azimuth. The flight trajectory is determined by the Antarctic wind patterns at float altitude. BOOMERANG's extremely sensitive bolometric detectors are cooled to < 0.3 K in a liquid helium/liquid nitrogen cryostat. Both the cryostat and the telescope, with its 1.3 m mirror, are mounted on the gondola's inner frame. Figures 2 and 3 show the instrument at two times during the 2003 Antarctic campaign.

The entire payload is hung on steel cables from a ~800,000 m^3 helium-filled balloon, provided by the NASA National Scientific Balloon Facility (NSBF now CSBF). Payloads can reach altitudes of 35 km, above about 99.5% of the Earth's noisy atmosphere. Ideally, the Antarctic vortex winds carry the instrument around the continent at latitude ~78 °S in 10–24 days. With 24 hours daylight, the Antarctic flight environment is thermally relatively stable, in contrast to day/night flights at lower latitudes.

After some two months of instrument integration and testing, BOOMERANG was launched on 6 January 2003 from McMurdo and terminated 15 days later. Despite dropping 171 kg of ballast, the payload altitude dropped daily. The flight path (Fig. 4) was further complicated by low-altitude winds which kept the balloon in the same spot for nearly five days. The payload landed on the Antarctic Plateau near Dome Fuji, at 3810 m *a.s.l.*, close to the Pole of Inaccessibility. In spite of the rather inconvenient final location, the data vessel was recovered within a week and the rest of the instrument salvaged the following year.

anisotropies in the CMB radiation field. Deviations from the mean intensity in the primordial plasma are in the order of 10^{-5} and for polarization are an order of magnitude smaller. It is these tiny deviations from uniformity that the BOOMERANG telescope targets.

The 2003 mission marked the instrument's second successful trip over the Antarctic. The first long-duration balloon flight, in December 1998, resulted in landmark, high signal-to-noise maps of the CMB intensity fluctuations (De Bernardis and others, 2000; Netterfield and others, 2002). For the latest flight the instrument was redesigned to be polarization sensitive and the attitude control system was upgraded to enable more accurate telescope pointing.

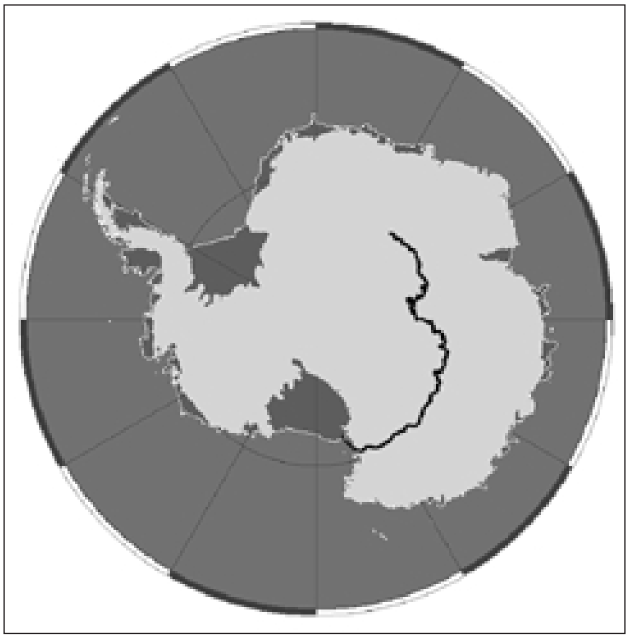

Figure 4
The BOOMERANG flight path. Figure provided by NSBF.

The final BOOMERANG sky coverage from the 2003 flight comprised ~195 hours of data over ~1.8% of the sky. The resulting BOOMERANG intensity maps are the most precise intermediate-scale measurement of CMB intensity anisotropy to date. The polarization measurement is roughly a 5σ detection. These can be used to constrain the cosmological parameters of the standard Big Bang model, *e.g.,* the energy density and geometry of the Universe. While the polarization data are not yet of an accuracy equivalent to the intensity data (*i.e.,* they cannot be used to independently constrain cosmological parameters) cross checks of best-fit cosmological parameters from both the polarization and intensity data indicate consistent results.

Efforts to obtain higher-precision measurements of the CMB polarization continue in order to provide an ever clearer picture of the origins of time and space. Canadians are involved in two upcoming projects which target CMB polarization measurements above and beyond the current detections. These include the Planck Satellite mission, for which the BOOMERANG detectors served as a testbed, and SPIDER, a future balloon-borne polarimeter. SPIDER will test the latest CMB detector technology during an around-the-world, 25-day flight from Alice Springs, Australia in 2010.

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First Light for the South Pole Telescope

Matt Dobbs
on behalf of the South Pole Telescope Collaboration

The South Pole Telescope (http://spt.uchicago.edu, SPT) is a mm-wavelength instrument designed to measure small angular scale features in the Cosmic Microwave Background (CMB) radiation. This afterglow light from the Big Bang was released when the universe was 400,000 years old – long before planets, stars, and galaxies had time to form.

The massive 10 m telescope (Ruhl and others, 2004) was deployed during the Antarctic summer 2006/7 by a team of scientists, engineers, and students from eight American institutions (Universities of California–Berkeley, California–Davis, Case Western Reserve, Chicago, Colorado–Boulder, Harvard-Smithsonian, Illinois and the Jet Propulsion Laboratory) and McGill University. The instrument's foundation, installed one year earlier, keeps the telescope afloat atop the 2500 m thick Antarctic ice sheet. The ground shields, which will be deployed and installed during the 2007/8 Antarctic summer, keep light reflected off the snow from entering the telescope optics.

The $19.2 million telescope is funded primarily by the National Science Foundation (NSF), with additional support from the Kavli Foundation of Oxnard, California, and the Gordon and Betty Moore Foundation of San Francisco. Canadian collaborators receive funding from the Le Fonds québécois de la recherche sur la nature et les technologies (FQRNT) and the Natural Sciences and Engineering Research Council of Canada (NSERC).

The telescope stands 75 feet (22.8 m) tall, measures 33 feet (10 m) across and weighs 280 tons (254 metric tons) (Fig. 1). It was assembled in Kilgore, Texas, then taken apart, shipped across the Pacific Ocean to New Zealand, and flown from there to the South Pole. Since November the SPT team has worked furiously to reassemble and deploy the telescope.

As with any construction project in extreme conditions, SPT was supported by a long and complex logistical chain stretching around the globe. All cargo to the South Pole is delivered by ski-equipped LC-130 aircraft, and the components must be able to be broken down to fit into the

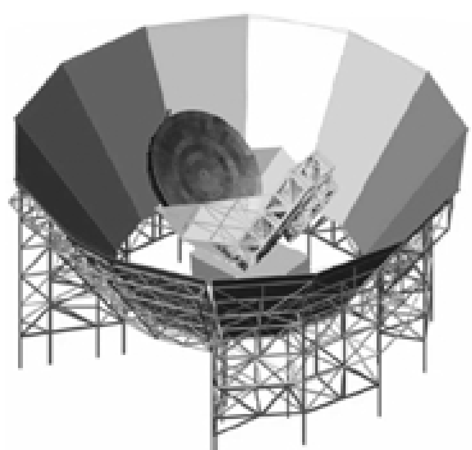

Figure 1
(Left) The 10 m South Pole Telescope installed during Antarctic summer 2006/7 at the Amundsen–Scott station (photo by S. Meyer, U. Chicago). (Right) Computer rendition of how the telescope will look after the ground shields are installed in the summer of 2007/8.

aircraft cargo bay. Flown by the New York Air National Guard, the aircraft are elements of Operation Deep Freeze, the military support arm of the U.S. Antarctic Program, which also includes Air Force cargo jets and U.S. Coast Guard icebreakers, Navy cargo handlers and many other logistical and personnel assets.

Astronomers work at the South Pole to take advantage of excellent viewing conditions. On the electromagnetic spectrum, the CMB falls somewhere between heat radiation and radio waves. This type of light is easily absorbed both by water vapour in the atmosphere and that emitted by the atmosphere. Situating the instrument at the South Pole minimizes this atmospheric foreground since the pole is high in elevation (2900 m), providing a thin atmosphere, and extremely dry, minimizing the water vapour content.

The snapshot of the early universe that will be created with the SPT encodes a wealth of information about its composition and evolution. Most exciting is the prospect of charting out the growth history of the universe, which today appears to be dominated by a mysterious accelerating constituent known as Dark Energy. The CMB radiation serves to backlight the entire universe, much like the light behind the screen in a shadow-puppet show. The largest gravitationally bound objects in the universe, galaxy clusters, will distort this light in a measurable way casting a shadow (like shadow puppets from our analogy) in the 2 mm wavelength CMB light. This distortion, called the Sunyaev–Zeldovich Effect (Sunyaev and Zeldovich, 1970), is an excellent tool for cosmology because the strength of the signal does not depend strongly on how far away the galaxy clusters are. This means we can see the clusters that are furthest away just as easily as we can see the close ones – a feature that is unique to this type of observation. The clusters that are observed and catalogued will act as tracers or test particles that can be used to reconstruct the expansion (growth) history of the universe and provide information about the nature of Dark Energy.

The large aperture of the telescope's primary dish makes the small angular resolution of the instrument possible, allowing the team to measure arc-minute-scale features accurately in the microwave background. In addition to excellent angular resolution, the instrument achieves exquisite sensitivity by making use of three novel technologies for its high-tech camera.

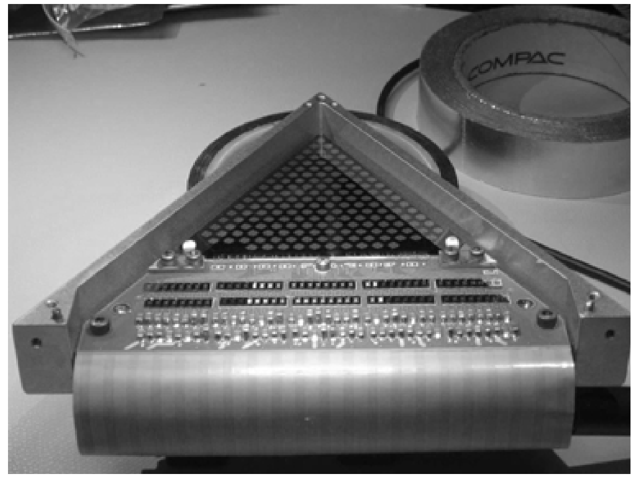

Figure 2
One of the six transition edge sensor arrays for the detector focal plane. Each silicon wafer (thin dark triangular piece) has 160 detectors which are sensitive to mm-wavelength light (photo by M. Dobbs).

The first of the technologies is the detector elements (Fig. 2). These sensors measure the intensity of incoming radiation (light) by completely absorbing the photons and allowing this incident power to heat up a small metallic absorber film. In contrast to the last generation of instruments, the temperature of the absorber is measured with a tiny film of superconductor called a transition edge sensor (TES). These TES detectors are an important advance because they can be fabricated lithographically as monolithic arrays with 100s or 1000s of detectors. The SPT focal plane contains 960 bolometric detectors whereas other mm-wavelength instruments currently in the field have only used several dozen detectors at most. These detectors need to be kept cold, about 0.25 K, to minimize the thermal noise that would otherwise obscure the weak signal from the sky. The easiest way to achieve these temperatures is by pre-cooling

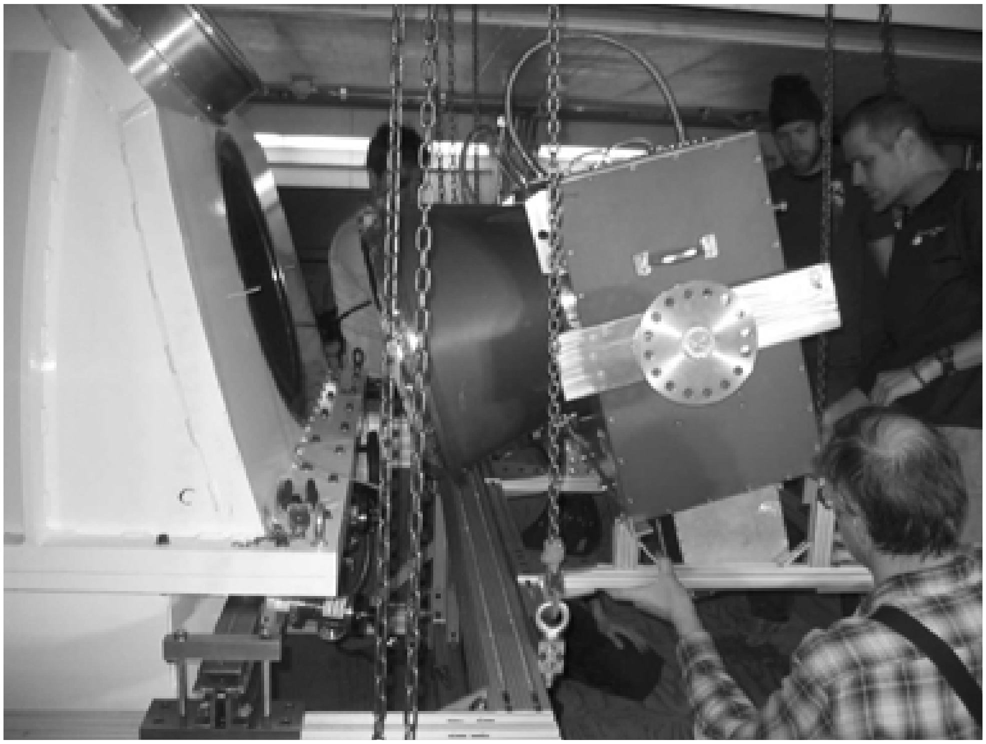

Figure 3
Sub-Kelvin temperature bolometer camera (centre) being mated with the cryostat (right) that houses the cold 4 K secondary mirror (photo by M. Dobbs).

a closed-cycle absorption fridge to 4 K with expendable liquid helium. This has been the standard strategy for most instruments to date. Instead, the SPT uses a mechanical pulse tube cooler to achieve its 4 K temperature stage. Making use of this technology required a dedicated research program to minimize the vibration interference produced by the moving parts of the cooler. By eliminating the expendable cryogens, the logistical support necessary for transporting liquid helium to the South Pole is removed. The third technological advance is the use of a novel superconducting multiplexed readout system that allows the signals from many bolometers to be encoded together on a single set of wires. While advanced multiplexing techniques are commonplace in room temperature electronics such as cell phones, employing this technology at sub-Kelvin temperatures where transistors cease to work requires a whole new toolset of superconducting components for the readout multiplexer. These advances make the SPT a technological pathfinder as well as providing a new scientific window on the universe.

Installation and commissioning of the SPT took most of the Antarctic summer. First astronomical light for the instrument was achieved on February 16, two days before the bulk of the science and installation team was evacuated from the South Pole station aboard the last flight of the season as the temperature started to plummet towards −50 °C, the no-fly limit for C-130 aircraft. This milestone was reached just ahead of the launch of the International Polar Year (IPY) research campaign – a fitting start to the IPY! The first test-observations for the telescope were maps of Jupiter that are being used for calibration and characterization of the instrument. First Light was a significant milestone for the project and a fitting conclusion to this summer's field campaign (Dobbs and others, 2006). Two scientists will remain at the research station for the winter; Steve Padin, the project scientist from the University of Chicago, and Zachary Staniszewski, a graduate student at Case Western Reserve University. The rest of the science team will support the field team while shifting their efforts from construction and testing over to the analysis of the rich data set that is being transmitted by satellite to North America. The team is concentrating its efforts now on fully characterizing the instrument before cosmological observations begin in early 2007.

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Dr Matt Dobbs (mdobbs@physics.mcgill.ca), a graduate of McGill University and the University of Victoria, holds the Canada Research Chair in Astro-particle Physics in the Department of Physics at McGill University.

First Research Cruise to Study Adaptations and Evolution of Fauna after the Collapse of the Larsen A and B Ice Shelves

Christine McClelland

The German Research Ship *Polarstern* left the harbour of Cape Town, South Africa, at 6 P.M. on November 23, 2006, with 97 crew members and scientists aboard. With humpback whales seeing us on our way, Leg 8 of the ANTXXIII expedition began as we sailed south. By December 1, we started to see evidence of the continent that lay ahead of us – icebergs. Despite the *Polarstern*'s superior ice-breaking capabilities, reaching Neumayer, the German base on Atka Bay in the Weddell Sea, took another 8 days (Fig. 1). After visiting and supplying Neumayer with food and fuel, we headed to our study area: the western Weddell Sea and Antarctic Peninsula.

Leg 8 of the ANTXXIII expedition brought together scientists from 14 countries (Belgium, Canada, Chile, Czech Republic, France, Germany, Italy, Mexico, Netherlands, Russian Federation, Spain, Ukraine, United Kingdom, and the United States of America) to work on two main research projects. The first was a continuation of ongoing studies on fisheries south of 60°S. As a member of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), Germany conducts surveys of the distribution, abundance, population structure and reproductive strategies of previously overexploited commercial fish species. Within the CCAMLR project, several smaller studies were performed, including fish population genetics and evolution. The study

Figure 1
The *Polarstern* in Atka Bay, Weddell Sea, with Christine McClelland, the sole Canadian scientist (photo by S. Schöling, Institut für Seefischerei).

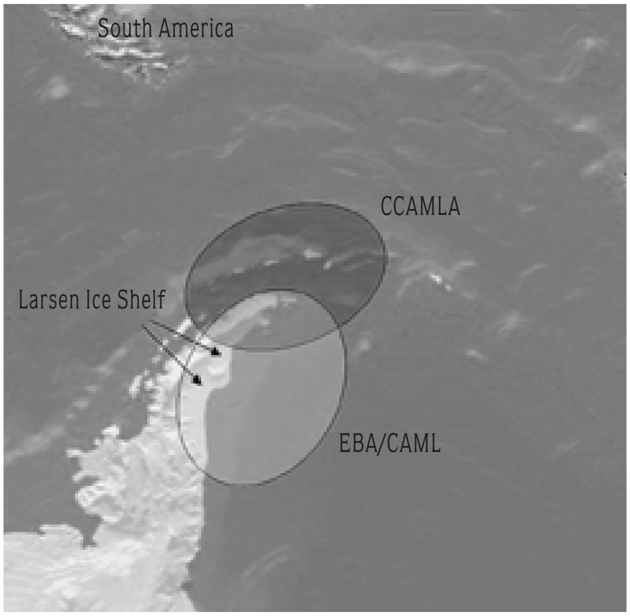


Figure 2
Map of the study areas for the two research programs conducted during Leg 8 of the *Polarstern*'s ANTXXIII cruise.

area for this project was Elephant Island, the South Shetland Islands and Joinville Island (Fig. 2).

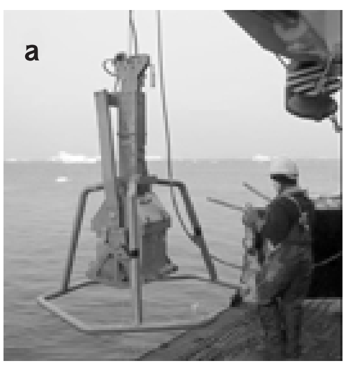
My work fell under the umbrella of the second project, conducted as part of the ANTXXIII Leg 8 which contributed to Evolution and Biodiversity in the Antarctic and Census of Antarctic Marine Life (EBA/CAML) by studying life in the Larsen A and B shelf areas. EBA was developed by the Scientific Committee on Antarctic Research while CAML is one of 14 field research projects headed by the Census for Marine Life. Both projects aim to study Antarctic organisms and their adaptations to the harsh climate in which they live. Studying how the animals survive in their environment in the past and present may shed light on how they will react when faced with the change being brought about by the warming of Antarctica. Numerous parameters of the ecosystem required investigation in order to identify key processes in the lives of Antarctic flora and fauna. The team of researchers used a remotely operated vehicle (ROV), Agassiz trawls, a CTD-equipped rosette water sampler, fish and amphipod traps, as well as multi, box and piston gravity corers (Figs 3 and 4). We were able to complete a series of five "full" stations where all CAML-related sampling occurred. The purpose of having "full" stations was that the data set produced would represent as many ecosystem parameters as we were able to sample.

The Larsen A and B areas, on the eastern side of the Antarctic Peninsula, have received considerable media coverage over the past 10 to 15 years. In 1995, the ice shelf covering Larsen A disintegrated and in 2002 that covering Larsen B did the same. Most scientists attribute the ice-shelf melting to increased Antarctic Peninsula temperatures as a result of global warming. This cruise was the first to investigate the organisms found in the Larsen A and B areas. For researchers, this was a unique opportunity to study the abundance, diversity and adaptations of marine animals in response to the collapse of the overlying ice shelves. We were also able to examine the recolonization process following the disturbance by iceberg keels scouring the sea floor at the time of ice-shelf disintegration.

As a part of the CAML program, I was involved in two projects during the cruise. My primary focus was measuring the respiration rates of benthic communities in order to study benthic–pelagic carbon cycles within the Larsen areas. Samples were collected using a 0.5 m × 0.5 m box corer. Subsamples from the box core were used to measure pigment concentration, bacteria abundance, grain size, carbon–hydrogen–nitrogen levels and faunal respiration incubations. The animals that were included in the incubations were echinoderms (brittle stars and sea cucumbers), amphipods, isopods, cumaceans, polychaetes and bivalves. Before the results can be published, I must first determine the contribution of primary production to the oxygen levels within the cores, analyze the faunal composition for each station, as well as review the sediment chemistry. I hope the results from this part of my onboard research will be the basis from which further, more in-depth, studies may develop.

Preliminary results from the second project on which I collaborated were available immediately. Part of the mandate of the CAML project was to develop a list of species

Figure 3
Sampling benthic invertebrates in Larsen B (photo by C. McClelland, CMN).



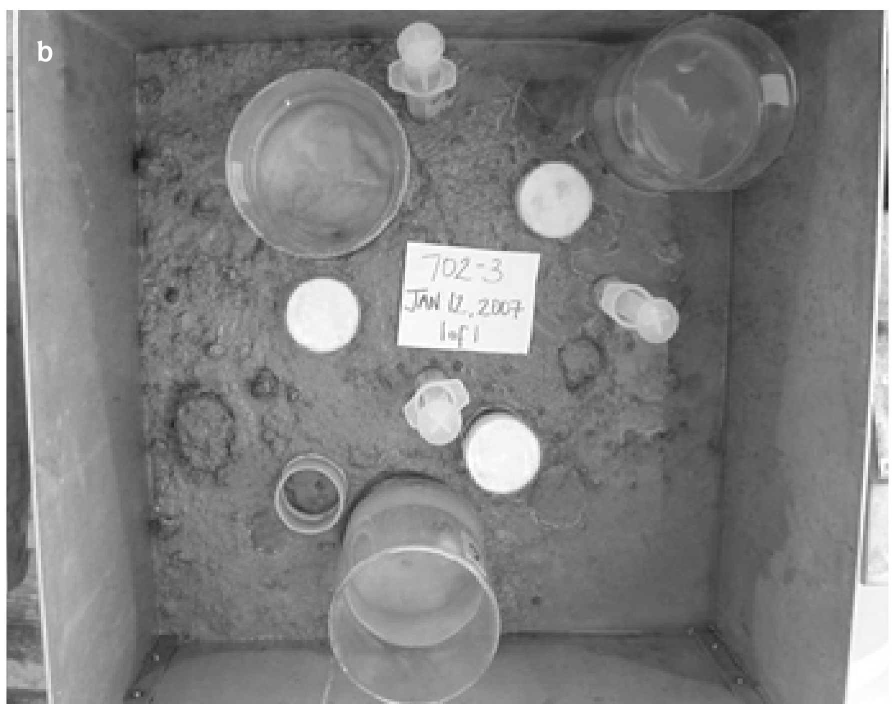


Figure 4
(a) Boxcoring in Larsen B (photo by G. Chapelle, International Polar Foundation) and
(b) an example of the boxcore subsamples (photo by C. McClelland, CMN).

present in the Larsen A and B areas. At the centre of attention were the benthic and epibenthic species. The Agassiz trawls were used to collect faunal samples from the sea floor. Taxonomists then removed the animals from the substrate and detritus. Among the most abundant of taxa were polychaetes, sponges, brittle stars, sea stars, sea cucumbers, isopods, amphipods, sea anemones and pycnogonids. Some trawls were full of hard coral, while others required additional winches to help lift the mass of sediment caught with the animals. There was a lot of excitement with every catch because with each one there was the possibility of finding

Figure 5
"The march of the Holothurians". Sea cucumbers curiously all heading in the same direction. Image taken by the ROV in the Larsen B area (photo courtesy of J. Gutt, AWI).

new species, since we were sampling areas that had never been sampled biologically before. In fact, preliminary results suggest there were a number of new and possibly endemic species found in a number of taxa, particularly amphipods. The chief scientist, Dr Julian Gutt (Alfred Wegener Institute), also aided CAML with footage from the ROV. Some of his preliminary results point to the presence of once-believed deep-sea species in areas above 300 m depth in the Larsen areas, showing the adaptation of deep-sea organisms to shallower water in the polar regions (Fig. 5). Data were also collected using both the ROV and a piston corer to confirm Eugene Domack's findings in 2004 of a cold seep deep in the Larsen B area. However, at the time of sampling on this cruise it seemed that the methane source had died away.

The list of described and possibly new species collected in the Larsen areas will be added to the database for Antarctic species. Our results will form the baseline from which further studies can continue. With increasing temperatures in the Antarctic, the studies started by this cruise will be invaluable for understanding the evolution and adaptations of organisms in the face of environmental change.

For more information about this cruise, browse the following web pages:

www.awi-bremerhaven.de
www.international-polar-year.de
www.polarfoundation.org
www.cousteau.org
www.caml.aq
www.ccamlr.org
www.eurekalert.org

Christine McClelland, a graduate of the University of Ottawa, has been working with Kathy Conlan at the Canadian Museum of Nature for the past four years. She plans to attend Memorial University of Newfoundland for post-graduate studies later this year.

Restoration of Shackleton's Nimrod Hut at Cape Royds

Gordon Macdonald of Vancouver Island (see *CARN,* vol. 20, November 2005, p. 16) is leading a team of building conservators restoring the Nimrod hut at Cape Royds, one of the world's most at-risk monuments. The hut was used by Sir Ernest Shackleton during his attempt on the South Pole nearly a century ago. The project is run by the Antarctic Heritage Trust with support from Antarctica New Zealand. A highlight will be a visit from Sir Edmund Hillary and the New Zealand Prime Minister who will be commemorating the 50th anniversary of the NZAP and Scott Base. The next project will be the conservation of Scott's Terra Nova Hut at Cape Evans.

News in Brief

Alain Grenier, Professor of nature tourism and sustainable development in the Département d'études urbaines et touristiques at the **Université du Québec à Montréal,** is interested in setting up a polar tourism research network and has proposed an organizational meeting to be held in Montréal 13–14 September 2007. Anyone interested in participating in such a network should contact Alain for further details (grenier.alain@uqam.ca).■

In addition to cruises by Canadian companies and the Students on Ice (SOI), several Canadians have been working in the Antarctic recently: **Kevin Hall (UNBC)** with the Italians; **Gordon Osinski (CSA)** with NASA; **Evgeny Pakhomov (UBC)** joined a winter cruise of the RV *Polarstern* to the Lazarev Sea (17 June to 21 August 2006) followed by **Christine McClelland (CMN)** over Christmas (23 November 2006 to 30 January 2007); **Gordon Macdonald** has returned to Cape Royds to complete restoration of the Nimrod Hut; BLAST (balloon-borne large aperture sub-millimetre telescope) involving scientists from **UofT, UBC** and **AMEC Dynamic Structures Ltd.** of Port Coquitlam was launched from McMurdo on 6 January 2007.■

The *Sedna IV* with **Damien Lopez** (chemist), **Sébastien Roy** and **Pascale Otis** (biologists) **(ISMER),** in a collaborative program with the Argentinians, wintered on the Antarctic Peninsula. The ship returned home in November 2006.■

Partly because Environment Canada was instrumental in helping to ratify the Protocol on Environmental Protection, and because that agency is now responsible for permitting Antarctic activities, the lead on the Antarctic file has now been transferred from the Department of Foreign Affairs and International Trade. It now resides with the Multilateral and Bilateral Affairs group within the International Affairs Branch, with day-to-day responsibility being handled by Guy-Serge Côté (guyserge.cote@ec.gc.ca).■

A highlight of the past year was the SCAR Open Science Meeting in Hobart. Canadian participation was less than at the previous meeting, but seven Canadians attended and 12 papers or posters were presented. SCAR now wants four national representatives named to each of the three Standing Scientific Groups (GeoSciences, Life Sciences and Physical Sciences). Anyone actively involved with any of these groups who is not currently identified as a national representative and would be interested in being so identified should contact either the Chair of CCAR (Wayne Pollard, pollard@geog.mcgill.ca) or the Executive Director of the Canadian Polar Commission (Steven Bigras, bigrass@polarcom. gc.ca).■

Geoff Green, Canadian adventurer, environmentalist and educator, was honoured by The Explorers Club with their Citation of Merit at its 103rd Annual Dinner on 17 March 2007. He founded Students on Ice (www.studentsonice.com), a non-profit organization that arranges educational expeditions for students to the Antarctic and the Arctic and is a veteran of 70 Antarctic and 30 Arctic expeditions.■

Valmar Kurol of the Montreal Antarctic Society has established an Antarctic Art Gallery of his paintings as a tribute to the International Polar Year. The pictures may be viewed at www.antarcticart.net.■

On 19 January 2007, a team of British explorers, led by Canadian **Paul Landry,** became the first expedition to reach the Antarctic Pole of Inaccessibility on foot. This Pole, the geographic centre of Antarctica, is the furthest point from any Antarctic coast. It lies just over 3700 m *a.s.l.* and is located approximately 83°S and 55°E, about 870 km northeast of the South Pole. The team took 49 days to complete the overland trip from the Russian base at Novolazarevskaya.■

In December 2006, **Serge Demers (ISMER)** signed a protocol with the Direction Nationale Antarctic (DNA) of Argentina whereby Argentina gives ISMER access to two houses at the Esperenza base for scientific investigations. One house is a laboratory and the other provides accommodation for six researchers.■

A group from New Zealand is attempting to build a platform for researchers from the social sciences and humanities by establishing an informal network called SHARE (Social sciences & Humanities Antarctic Research Exchange, www.share-antarctica.org). The network would be designed to further international collaboration, establish more structural forms of collaboration and facilitate the provision of political, logistical and financial support. An official announcement on SHARE will be published in the July 2007 special issue on Polar Tourism of the journal *Tourism in Marine Environments.*■

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