Paolo de Bernardis and Andrew Lange

2006 Balzan Prize for Observational Astronomy and Astrophysics
For their contributions to cosmology, in particular the BOOMERanG Antarctic balloon experiment.

Observation of the Cosmic Microwave Background (CMB)
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Observations of the finest details of the Cosmic Microwave Background (CMB) have the potential to explain some of the unresolved problems of modern cosmology, such as the existence of an inflation process in the very early Universe, the existence and the nature of dark matter and dark energy, and the formation of structures in the Universe. Paolo de Bernardis and Andrew Lange have used the second half of their Balzan Prize to finance two experimental investigations: one on CMB polarization and the other on the formation of cosmic structures. Tragically, Andrew Lange died on 22 January 2010. His colleagues James Bock, Sunil Golwala, and Tom Soifer at the California Institute of Technology are now managing his Balzan research project.

1. *An experimental investigation of CMB polarization*, carried out under the responsibility of professor Andrew Lange until his death. This project is aimed at measuring the B-modes of CMB polarization, the signature of the Inflation Process. Half of the second part of the Balzan Prize to Lange is being used to support the work of young physicists (several of whom earned their Ph.D.s working on *BOOMERanG*) to pioneer the new technologies and methods that will be necessary to search for the signature of Inflation in the CMB. These technologies will be deployed in telescopes now operating at the South Pole, and on a new balloon-borne telescope, called SPIDER, that will circumnavigate the globe from Australia. The following activities have been supported:
- The development of the SPIDER experiment, a new-generation balloon-borne polarimeter for the measurement of the polarization of the Cosmic Microwave Background at medium and large angular scales (B.P. Crill, A. E. Lange, et al.). The instrument hardware is now being completed, and will be flown in 2011. The very large arrays of ultra-sensitive bolometric detectors developed in Caltech-JPL (Lange's group) combined with the favorable environment of a stratospheric balloon flight make this instru-

ment the most ambitious CMB polarization experiment being flown before a future satellite mission. The latter is also being studied with extreme care in both Lange's and de Bernardis' groups (J. Bock, A.E. Lange, et al. (EPIC Collaboration) and P. de Bernardis, M. Bucher, C. Burigana, L. Piccirillo).
- Data analysis of the QUaD experiment, which has measured the anisotropy and the polarization of the CMB at sub-degree angular scales (A.R. Ade, A.E. Lange, et al. (QUaD Collaboration)).
- Hardware and the personnel running the BICEP instrument, deployed to the South Pole for measuring the polarization in the CMB at degree scales (H.C. Chiang, A.E. Lange, et al.).

2. *An experimental investigation of the first stages of the formation of cosmic structures*, carried out under the responsibility of professor Paolo de Bernardis. This project is aimed at measuring the effect of the first structures on the background CMB light: in fact effects like the Sunyaev-Zeldovich in the first clusters of Galaxies and resonant lines in the first structures leave an imprint in the CMB, which can be used to trace them. Half of the second part of the Balzan Prize to de Bernardis was used to acquire hardware to complete the instruments, to support the dedicated work of post-docs already trained on the BOOMERanG project, to support the collaboration with the Cardiff (Ade, Mauskopf) and Pasadena (Lange) groups for the development of subsystems, and the diffusion of cosmology results through the preparation of a book on observational cosmology. The following activities have been supported:
- Three post-doc fellowships at La Sapienza, focusing on the data analysis of the BOOMERanG and Planck experiments (M. Veneziani, P. de Bernardis, et al.) and on the SAGACE study (see below) have been assigned. One fellowship has been assigned to Dr. Gianluca Polenta. After this activity, he is now a scientist at the Agenzia Spaziale Italiana Data Center (ASDC). A second fellowship has been assigned to Dr. Luca Lamagna, who is now a Researcher (TD) with de Bernardis' group in La Sapienza. The third fellowship has been assigned to Dr. Alessandro Schillaci, and he is currently active in de Bernardis' group.
- Support for the hardware of the large throughput Martin-Puplett interferometer built in our group. This instrument is a prototype for the satellite mission described below. This has been the subject of the Ph.D. thesis of Dr. Alessandro Schillaci *"Millimetric spectropolarimetry of cosmological signals"* discussed in Dec. 2009 at La Sapienza.
- The full phase-A study of an innovative satellite mission, called SAGACE, carried out by the Rome-Sapienza group in the framework of the second project above. A short description of this activity is presented in *SAGACE: the Spectroscopic Active Galaxies*

And Clusters Explorer. The full study has been described in a long document (ref. KI-SAG-RP-010), which has been submitted to the Italian Space Agency for evaluation and possible implementation as a national small mission.
- A study of the possibility to measure dark matter using high resolution observations of clusters of galaxies, presented in S. Colafrancesco, P. de Bernardis, S. Masi, G. Polenta, P. Ullio, *Direct probes of Dark Matter in the cluster 1ES0657-556 through microwave observations,* 2007.
- A book on observational cosmology for the general public, written by Prof. Paolo de Bernardis (P. de Bernardis, *Osservare l'Universo*, Il Mulino, Bologna, 2010).

Publications (in chronological order):
- S. Colafrancesco, P. de Bernardis, S. Masi, G. Polenta, P. Ullio, *Direct probes of Dark Matter in the cluster 1ES0657-556 through microwave observations*, "Astronomy and Astrophysics", 467, 1, 2007.
- B. P. Crill, A. E. Lange, et al., *SPIDER: A Balloon-borne Large-scale CMB Polarimeter*, in *Space Telescopes and Instrumentation 2008: Optical, Infrared, and Millimeter,* Jacobus M. Oschmann, Jr.; Mattheus W. M. de Graauw; Howard A. MacEwen (Editors), Proceedings of SPIE, Volume 7010, 2008.
- J. Bock, A.E. Lange, et al. (EPIC Collaboration), *Study of the Experimental Probe of Inflationary Cosmology (EPIC)-Intemediate Mission for NASA's Einstein Inflation Probe*, arXiv:0906.1188.
- J. Bock, A.E. Lange, et al. (EPIC Collaboration*), The Experimental Probe of Inflationary Cosmology (EPIC): A Mission Concept Study for NASA's Einstein Inflation Probe,* arXiv:0805.4207.
- P.A.R. Ade, A.E. Lange, et al. (QUaD Collaboration), *First season QUaD CMB temperature and polarization power spectra, "*The Astrophysical Journal", 674, 22-28, 2008.
- P.A.R. Ade, A.E. Lange, et al. (QUaD Collaboration), *Second and third season QUaD CMB temperature and polarization power spectra, "*The Astrophysical Journal", 692 , 1247-1270, 2009.
- P. de Bernardis, M. Bucher, C. Burigana, L. Piccirillo, *B-Pol: Detecting Primordial Gravitational Waves Generated During Inflation*, "Experimental Astronomy", 23, 5-16, 2009.
- M. Veneziani, P. de Bernardis, et al. *"Sub-Degree Sunyaev-Zel'dovich Signal from Multi-Frequency BOOMERanG observations"*, "The Astrophysical Journal", 702, L61-L65, 2009.
- H. C. Chiang, A.E. Lange, et al., *Measurement of Cosmic Microwave Background Po-*

larization Power Spectra from Two Years of BICEP Data, "The Astrophysical Journal", 711, 1123-1140, 2010.
- P. de Bernardis, et al., *SAGACE: the Spectroscopic Active Galaxies And Clusters Explorer*, proc. of the 12th Marcel Grossman Meeting, R. Jantzen R. Ruffini eds., Paris, 2010, astro-ph/1002.0867.
- P. de Bernardis, *Osservare l'Universo*, Il Mulino, Bologna, 2010.

Statements by the Prizewinners and by James Bock and Tom Soifer:
Il Premio Balzan è per noi non solo un riconoscimento delle attività e dei risultati della collaborazione BOOMERanG, ma anche una iniezione di speranza per le attività future nostre e dei giovani ricercatori e collaboratori. Nella situazione contingente di generale recessione delle risorse umane e finanziarie nell'università e nella ricerca in Italia, il contributo del premio permetterà la continuità delle nostre attività e la formazione di altri giovani. Paolo de Bernardis (Rome, 24.11.2006)

It is impossible to predict how and when we will finally understand the nature of the dark energy and dark matter that we now believe comprise most of the universe, or how and when we will understand the physics of the inflation that we believe spawned our observable Universe. It is especially fitting then, that the Balzan Foundation stipulates that half of the Prize be used to support the research of young scientists, for it is they who will make the next set of breakthroughs. I hope that my portion of the research funds will support new efforts by young scientists to peer yet further back in time, to the moment of Inflation itself, using a new generation of telescopes at the South Pole and on high-altitude balloons. Andrew Lange (Rome, 24.11.2006)

We are saddened to report the death of Andrew Lange on 22 January 2010 under tragic circumstances. Andrew Lange left his imprint on the CMB community through his research, but perhaps even more profoundly through the network of people he guided and influenced, including his current and former students and postdocs, and his many professional colleagues. His loss has been felt both widely and deeply in experimental cosmology. The research supported by the Balzan Foundation, directed to supporting younger researchers, continues on and is managed by his close colleagues James Bock, Sunil Golwala, and Tom Soifer at the California Institute of Technology. James Bock and Tom Soifer (2010)