FINDING THE BIG BANG

Cosmology, the study of the universe as a whole, has become a precise physical science, the foundation of which is our understanding of the cosmic microwave background radiation (CMBR) left from the big bang. The story of the discovery and exploration of the CMBR in the 1960s is recalled for the first time in this collection of 44 essays by eminent scientists who pioneered the work.

Two introductory chapters put the essays in context, explaining the general ideas behind the expanding universe and fossil remnants from the early stages of the expanding universe. The last chapter describes how the confusion of ideas and measurements in the 1960s grew into the present tight network of tests that demonstrate the accuracy of the big bang theory.

This book is valuable to anyone interested in how science is done, and what it has taught us about the large-scale nature of the physical universe.

P. JAMES E. PEEBLES is Albert Einstein Professor of Science Emeritus in the Department of Physics at Princeton University, New Jersey.

LYMAN A. PAGE, JR. is Henry DeWolf Smyth Professor of Physics in the Department of Physics at Princeton University, New Jersey.

R. BRUCE PARTRIDGE is Marshall Professor of Natural Sciences at Haverford College, Pennsylvania.
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P. JAMES E. PEEBLES,
Princeton University, New Jersey

LYMAN A. PAGE JR.
Princeton University, New Jersey

and

R. BRUCE PARTRIDGE
Haverford College, Pennsylvania
To the memory of Dave Wilkinson
for his leadership in measuring
the fossil radiation
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Preface

This is the story of a major advance in science, the discovery of fossil radiation left from the early stages of expansion of the universe – the big bang. Colleagues in informal conversations now only vaguely recalled led us to realize that this story is particularly worth examining because it happened in what was then a small line of research, and one that still is relatively simple compared to many other branches of physical science. That makes it well suited for an examination of how science actually is done, warts and all, in all the details – usually too numerous to mention – recalled by many of the people who did the work.

All the main steps in this story – the prediction, detection, identification, and exploration of the properties of the fossil radiation from the big bang – have been presented in histories of science. But these histories do not have the space (or the aim) to give an impression of what it was like to live through those times. We sense a similar feeling of incompleteness in many histories of science written by physicists, as well as by professional historians and sociologists. And there is a well-established remedy: assemble recollections from those who were involved in the work. An example in the broader field of cosmology – the study of the large-scale structure of the universe – is the collection of interviews in Origins: the Lives and Worlds of Modern Cosmologists (Lightman and Brawer 1990). We follow that path, but in more detail in a more limited line of research.

Early studies of the fossil radiation involved a relatively small number of people in what has proved to be a considerable advance in establishing the physical nature of the universe. This means we could aim for complete coverage of recollections from everyone involved in the early work who is still with us. We did not reach completeness: we suppose it is inevitable that a few colleagues would have reasons not to want to take part. We are fortunate, however, that almost everyone we could contact was willing to
contribute recollections. All are well along in life now, but they have not slowed down; all had to break away from other commitments to complete their assignments. We are deeply indebted to the contributors for taking the time and trouble to make this collection possible, and for their patience in enduring the lengthy assembly of the book.

We are grateful to participants also for help in weeding out flaws in the introductory chapters, the collection of essays, the concluding chapter and Appendix which both treat what has grown out of the early work, and the Glossary that is meant to guide the reader through the story. We have also benefited from advice from those who started working in this subject more recently and have taken part in its growth into the present large and active science we outline in the concluding chapter. Their stories are important, but to keep the numbers manageable in the style of this book we had to impose a limit to recollections from people who were involved in this subject before 1970. That is when activity started gathering strength for the next leaps of technology and theory in increasingly large research groups.

Rashid Sunyaev was an invaluable guide to contacting contributors in Russia. We are grateful for help in the discussion in Chapter 3 of early measurements of the microwave radiation background from Eiichiro Komatsu and Tsuneaki Daishido, who led us to Haruo Tanaka’s recollections of his work in Japan, from James Lequeux, who recalls early work in France, Virginia Trimble, who gives a picture of Gamow’s thinking, and Jasper Wall, who led us to Covington’s work in Canada. We have descriptions of the origins of the critical radiation energy spectrum measurements from Mark Halpern, Michael Hauser, and Ed Wishnow, and of the development of ideas on the distortion of the radiation spectrum from Ray Weymann. Ed Cheng helped us trace the origins of the WMAP satellite mission. We thank Steve Boughn, Josh Gundersen, Shaul Hanany, Gary Hinshaw, Norm Jarosik, Al Kogut, Paul Richards, John Ruhl, Suzanne Staggs, and Juan Uson for their help in entering and correcting the tabulation of experiments in Table A.3 in the Appendix, though of course all remaining errors are of our doing. We are grateful to Neta Bahcall, Joanna Dunkley, Brian Gerke, Toby Marriage, Jerry Ostriker, Will Percival, Bharat Ratra, David Spergel, Paul Steinhardt, and Ned Wright for help and advice on the cosmological tests; Michael Gordin for his instructions on similar collections of personal histories in other fields of science and on the lessons to be drawn from them; Mike Lemonick for help with his interview of David Wilkinson and his guidance to the art of communicating science; and Tatiana Medvedeva and Marina Anderson for their translations. Ned Conklin, Michael Fall, Masataka Fukugita, Martin Harwit, Michael Hauser, Malcolm Longair, Alison Peebles,
Bharat Ratra, and John Shakeshaft were particularly helpful guides to the presentation of the science and history of this subject, and to a substantial reduction of the error rate. They certainly do not share the blame for our remaining flaws of commission and omission.

Some steps toward the organization of this project ought to be recorded. Bernie Burke, Lyman Page, Jim Peebles, Alison Peebles, Tony Tyson, Dave Wilkinson, Eunice Wilkinson, and Bob Wilson met in Princeton on 9 February 2001, for an informal discussion over dinner of the story of the detection and identification of the fossil radiation. Wilson’s written notes agree with Peebles’ undocumented recollection of the general consensus that the story is worth telling. But we all returned to other interests. In a second attempt to get the project started, George Field, Jim Peebles, Pat Thaddeus, and Bob Wilson met at Harvard on 8 August 2003. This led to a proposal that was circulated to some 12 proposed contributors. (The number is uncertain because we did not keep records.) It yielded three essays – they are in this collection – but attention again drifted to other things. The third attempt commenced with a discussion between Bruce Partridge and Jim Peebles in September 2005 at the Princeton Institute for Advanced Study. That discussion led to a blunt actuarial assessment: if the story were to be told in a close to complete way it would have to be done before too many more years had passed. That generated the momentum that led to completion of the project.

We sent a proposed outline of the book with an invitation to contribute to 28 people on 7 December 2005. As one might expect, the outline for the book continued to change after that as we better understood what we were attempting to do. A more unsettling change is that although we had given the list of contributors careful thought, we continued to identify people who ought to contribute: we have in this book some dozen additions to the December 2005 list. A simple extrapolation suggests we have forgotten still others: we likely have not been as complete as we ought to have been. We hope those we inadvertently did not include will accept our regrets for our inefficiency. We hope all who did contribute to this book, in many ways, are aware of our gratitude.

Many of the figures were made for this book, whereas some were made by the contributors many years ago. Where we have reason to think a figure was published elsewhere and the rightsholder is not the contributor we have obtained permission to reproduce. We apologize in advance for any omissions in this procedure.
List of contributors

J. Richard Bond
Canadian Institute for Theoretical Astrophysics
University of Toronto
Ontario, Canada

Stephen Boughn
Department of Astronomy
Haverford College
Haverford, PA, USA

Paul Boynton
Department of Physics
University of Washington
Seattle, WA, USA

Ronald N. Bracewell
STAR Lab, Stanford University
Stanford, CA, USA

Geoffrey R. Burbidge
Department of Physics
University of California
San Diego, CA, USA

Bernard F. Burke
MIT Kavli Institute for Astrophysics and Space Research
Cambridge, MA, USA

Edward K. Conklin
Honolulu, HI, USA

Karl C. Davis
Richland, WA, USA

Andrei Georgievich Doroshkevich
Astro Space Center
Moscow, Russia

George F. R. Ellis
Mathematics Department
University of Cape Town
Cape Town, South Africa

John Faulkner
Astronomy and Astrophysics Department
University of California
Santa Cruz, CA, USA

George B. Field
Harvard-Smithsonian Center for Astrophysics, Harvard University
Cambridge, MA, USA

Martin Harwit
Cornell University
Washington, DC, USA
List of contributors

Paul S. Henry
AT&T Laboratories
Middletown, NJ, USA

David C. Hogg
Boulder, CO, USA

Michele Kaufman
Department of Physics, Ohio State University, Columbus, OH, USA

David Layzer
Belmont, MA, USA

Malcolm S. Longair
Cavendish Laboratory, University of Cambridge, Cambridge, UK

Jayant V. Narlikar
IUCAA, Pune, India

Igor Dmitriyevich Novikov
Astro Space Center, P.N. Lebedev Physics Institute, Moscow, Russia

Donald E. Osterbrock
Lick Observatory
University of California
Santa Cruz, CA, USA

R. Bruce Partridge
Department of Astronomy
Haverford College
Haverford, PA, USA

P. James E. Peebles
Department of Physics
Princeton University
Princeton, NJ, USA

Arno Penzias
New Enterprise Associates
Menlo Park, CA, USA

Judith L. Pipher
Department of Physics and Astronomy, University of Rochester, Rochester, NY, USA

Martin Rees
Institute of Astronomy, Cambridge University, Cambridge, UK

Peter G. Roll
Georgetown, TX, USA

Rainer K. Sachs
Department of Mathematics
University of California
Berkeley, CA, USA

John R. Shakeshaft
St. Catharine's College, University of Cambridge, Cambridge, UK

Kandiah Shivanandan
Bethesda, MA, USA

Joe Silk
Department of Physics
University of Oxford
Oxford, UK

Yuri Nikolaevich Smirnov
Russian Research Center
“Kurchatov Institute”
Moscow, Russia

Kazimir S. Stankevich
Radiophysical Research Institute
Nizhny Novgorod, Russia

Robert A. Stokes
Versa Power Systems, Inc.
Littleton, Colorado, USA
List of contributors

Rashid Sunyaev
Max-Planck-Institut für
Astrophysik, Garching
Germany, and
Space Research Institute
Moscow, Russia

Patrick Thaddeus
Harvard-Smithsonian Center for
Astrophysics, Harvard University
Cambridge, MA, USA

Kenneth C. Turner
Carrollton, GA, USA

Robert V. Wagoner
Department of Physics, Stanford
University, Stanford, CA, USA

Jasper V. Wall
Department of Physics and
Astronomy, University of British
Columbia, Vancouver, Canada

Rainer Weiss
LIGO Group, MIT Kavli
Institute for Astrophysics and
Space Research
Cambridge, MA, USA

William “Jack” Welch
Department of Astronomy
University of California
Berkeley, CA, USA

David T. Wilkinson
Department of Physics
Princeton University
Princeton, NJ, USA

Robert W. Wilson
Harvard-Smithsonian Center for
Astrophysics, Harvard University
Cambridge, MA, USA

Arthur M. Wolfe
Department of Physics, University of
California, San Diego, CA, USA

Neville J. Woolf
Steward Observatory, University of
Arizona, Tucson, AZ, USA

Jer-tsang Yu
Office of the CIO, City University
of Hong Kong, Hong Kong SAR
China