Fundamental Questions of Practical Cosmology

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Fundamental Questions of Practical Cosmology

Exploring the Realm of Galaxies

Springer

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Preface

Allan Sandage used the term "Practical cosmology" to denote the study of the large-scale universe and the search for the world model which best describes it. In our book we, as students of practical cosmology, guide the reader through modern cosmology, with emphasis on cosmological physics within our gradually deepening sample of the universe. We have restricted this treatise to the realm of galaxies where we can measure distances to individual objects, which in itself is a classical and fundamental problem in astronomy. Therefore, our discussion of the problems of the early universe and the cosmic background radiation and its angular fluctuations, so central in modern cosmology in general, is relatively limited.

This book presents cosmology as a physical science based on observations, experiments and theoretical interpretations. We remind the reader that fundamental physics as understanding of natural phenomena, including the whole universe, is the modern *Philosophiae Naturalis* started by Galileo and Newton. We do not presuppose advanced knowledge of astronomy and do not go into detailed descriptions of observing techniques. Basic mathematical concepts used in modern cosmological models are presented in a simple way. We hope that all this will make the book useful for both astronomers and general physicists, and also for university students of physical sciences. If needed, suitable background reading on astronomy may be found in the book by Karttunen et al.: "Fundamental Astronomy" (Springer 2006), and on history of astronomy and cosmology in Teerikorpi et al.: "The Evolving Universe and the Origin of Life—The Search for Our Cosmic Roots" (Springer 2009). The development of the Cosmological Principle has been discussed by Baryshev and Teerikorpi: "Discovery of Cosmic Fractals" (World Scientific 2002).

The following subjects are close to our own experience in the study of the galaxy universe and form the main contents of the book: The cosmic distance scale and the Malmquist bias. Gravitation and world models. Observational tests of cosmological models. The large-scale structure of the universe. Conceptual problems of cosmological physics.

We emphasize those aspects which give practical cosmology its special character, due to a subtle interplay between observations, data analysis, and fundamental physics. We hope that our book will help the reader to achieve useful conceptual

understanding of some central but not so often emphasized problems in modern cosmology (such as selection effects and methods of analysis of the large-scale structure).

We underline throughout the book the essential fact that to obtain the correct picture of cosmological physics one should be aware that cosmology is—in a sense—"a science of cosmic selection effects". The interpretations from directly observed astronomical quantities and from astronomical data in general, may be in a subtle manner distorted by physical and technical limitations of observations and by inadequate methods of data analysis.

Cosmology has not been finished yet, and many fundamental questions are still open problems. The late Edward Harrison wrote to us in a letter: "Cosmology is always in the state of triumph and crisis. It is the natural state of the art." And this is because the initial assumptions and physical consequences are often difficult or impossible to test directly. There is the need for continuous testing of the accepted cosmological framework, which is, in the terminology of Thomas Kuhn, the working paradigm which rules and inspires contemporary cosmologists. Assumptions made by cosmologists determine the theory, its predictions and the inferred properties of deep space phenomena. At the same time the assumptions themselves are open for investigation—a constructive duality. Therefore we also wish to point out the positive role of alternative cosmological ideas which serve as a test-bench on the way towards a true world model.[1]

In principle, one would like to see practical cosmology as wider based than any specific cosmological model. This is because its methods are especially aimed at testing the initial assumptions and basic predictions of different world models. It should guide cosmologists between the Scyllas of empirism and the Charybdises of pure thinking ever tempting us away from the correct route towards progressively closer approximations to the true world model and to a deeper understanding of Reality.

We wish to mention with gratitude several people whose collaboration with us or whose own work have made this book possible. Some of them have also read parts of the manuscript.

Andrej Berdyugin, Lucette Bottinelli, Alexander Butkevich, Gene Byrd, Arthur Chernin, Timo Ekholm, Chris Flynn, Andrea Gabrielli, Lucienne Gouguenheim, Alik Gromov (†), Mikko Hanski, Toivo Jaakkola (†), Michael Joyce, Igor Karachentsev, Boris Komberg, Francesco Sylos Labini, Ari Lehto, Benoit Mandelbrot (†), Georges Paturel, Luciano Pietronero, Fred Rost, Allan Sandage (†), Vladimir Sokolov, Gilles Theureau, Mauri Valtonen.

We dedicate our book to the memories of Allan Sandage (1926–2010), Geoffrey Burbidge (1925–2010), and Benoit Mandelbrot (1924–2010). In the 20th century, Sandage represented the classical approach to observational cosmology, Burbidge

[1] During the preparation of the book we organized the conference *Problems of Practical Cosmology* held in St.Petersburg in June 2008. The meeting offered examples of mainstream and critical views, both of which are fruitful for the advancement of cosmological physics (Proceedings at http://ppc08.astro.spbu.ru).

defended alternative cosmological views, and Mandelbrot introduced novel mathematical concepts for describing cosmologically distributed matter. We hope that we have been able to convey, not only their specific contributions to cosmology, but also some of their spirit of approach to science.

St.Petersburg, Russia — Yurij Baryshev
Paimio, Finland — Pekka Teerikorpi

About the Authors and the Book

Dr. Yurij Baryshev (b. 1948) works as Senior Research Associate at the Astronomical Institute of St.Petersburg University, Russia. He has done research in various fields of extragalactic astronomy and cosmology, where his main research interest is relativistic astrophysics including cosmology and gravity physics. He has investigated Einstein's and Feynman's approaches to gravitation, active galactic nuclei, quasars, gravitational radiation, gravitational lensing by dark matter, and crucial cosmological tests. He has also studied the implications for cosmology of the recent discovery of the dark energy component and the fractal structure of the luminous matter distribution. He has been working as invited professor at the Rome University "La Sapienza" (Italy) and at the Lyon University (France). He has co-authored with P. Teerikorpi the book on the history of the Cosmological Principle *Discovery of Cosmic Fractals* (World Scientific 2002).

Dr. Pekka Teerikorpi (b. 1948) works as Senior Research Associate at Tuorla Observatory of the Department of Physics and Astronomy of Turku University. He has done research in various fields of Galactic and extragalactic astronomy and practical cosmology, with special interest in the selection effects and biases influencing the determination of the cosmic distance scale and the value of the Hubble constant. He has also made excursions to the Milky Way (the rotation curve, interstellar dust), the realm of active galactic nuclei and the problem of the local detection of dark energy. He has co-authored with Yu. Baryshev the book on the history of the Cosmological Principle *Discovery of Cosmic Fractals* (World Scientific 2002) and has recently written, together with a few other astronomers and exobiologists the book *The Evolving Universe and the Origin of Life—The Search for our Cosmic Roots* (Springer 2009), telling about the history and spirit of our science.

The book guides the reader (astronomer, physicist, university student) through central questions of Practical Cosmology, a term used by the late Allan Sandage to denote the modern scientific enterprise to find out the cosmological model best describing the universe of galaxies, its geometry, size, age, and material contents. The authors draw from their personal experience in astrophysics and cosmology to explain key concepts of cosmology, both observational and theoretical, and to highlight several items which give cosmology its special character:

– idiosyncratic features of the "cosmic laboratory"
– Malmquist bias in determination of cosmic distances
– theory of gravitation as a cornerstone of cosmological models
– crucial tests checking the reality of space expansion
– methods of analyzing the structures of the universe as mapped by galaxies
– usefulness of fractal as a model to describe the large-scale structure
– new cosmological physics inherent in the Friedmann world model

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