

# Jürgen Ehlers

In the 1950s the mathematical department of Hamburg University, with its stars Artin, Blaschke, Collatz, Kähler, Peterson, Sperner and Witt had a strong drawing power for Jürgen Ehlers, student of mathematics and physics. Since he had impressed his teachers he could well have embarked on a distinguished career in mathematics had it not been for Pascual Jordan and – I suspect – Hermann Weyl’s *Space–Time–Matter*.

Jordan had just published his book “*Schwerkraft und Weltall*” which was a text on Einstein’s theory of gravitation, developing his theory of a variable gravitational “constant”. Only the rudiments of this theory had been formulated and Jordan, overburdened with countless extraneous commitments, was eager to find collaborators to develop his theory. This opportunity to break new ground in physics enticed Jürgen Ehlers and Wolfgang Kundt to help Jordan with his problems, and their work was acknowledged in the 1955 second edition of Jordan’s book.

It didn’t take Jürgen, who always was a systematic thinker, long to realize that not only Jordan’s generalization but also Einstein’s theory itself needed a lot more work. This impression was well described by Kurt Goedel in 1955 in a letter to Carl Seelig: “My own work in relativity theory refers to the pure gravitational theory of 1916 of which I believe that it was left by Einstein himself and the whole contemporary generation of physicists as a torso – and in every respect, physically, mathematically, and its applications to cosmology”.

When asked by Seelig to elaborate, Goedel added: “Concerning the completion of gravitational theory of which I wrote in my last letter I do not mean a completion in the sense that the theory would cover a larger domain of phenomena (Tatsachenbereich), but a mathematical analysis of the equations that would make it possible to attempt their solution systematically and to find their general properties. Until now one does not even know the analogs of the fundamental integral theorems of Newtonian theory which, in my opinion, have to exist without fail. Since such integral theorems and other mathematical lemmas would have a physical meaning, the physical understanding of the theory would be enhanced. On the other hand, a closer analysis of the physical content of the theory could lead to such mathematical theorems”.

Such a view of Einstein's theory was also reflected in the talks and discussions of the "Jordan Seminar". This was a weekly meeting of Jordan's coworkers in the Physics Department of Hamburg University to discuss Jordan's theory of a variable gravitational scalar. However, under Jürgen's leadership, the structure and interpretation of Einstein's original theory became the principal theme of nearly all talks. Jordan, who found little time to contribute actively to his theory, reluctantly went along with this change of topic. Through grants from the US Air Force and other sources he provided the logistic support for his research group. For publication of the lengthy research papers on Einstein's theory of gravitation by Ehlers, Kundt, Ozsvath, Sachs and Trümper, he made the proceedings of the Akademie der Wissenschaften und der Literatur in Mainz available. Jordan appeared often as coauthor, but I doubt whether he contributed much more than suggestions in style, like never to start a sentence with a formula. Some results were also written up as reports for the Air Force and became known as the Hamburg Bible.

It was a principal concern in Jürgen's contributions to Einstein's theory to clarify the mathematics, separate proof from conjecture and insist on invariance as well as elegance. This clear and terse style, which always kept physical interpretation in mind, appeared already in his Hamburg papers. His work in relativity resulted not only in books, published papers, supervised theses, critical remarks in discussions and suggestions for future work. By establishing the "Albert-Einstein-Institut" Jürgen designed a unique international center for research in relativity. As the founding director of this "Max-Planck-Institut für Gravitationsphysik" in Brandenburg, he has led it to instant success. Through his leadership, research on Einstein's theory in Germany is flourishing again and his work and style has set a standard for a whole generation of researchers.

Engelbert Schücking

# Preface

The contributions in this book are dedicated to Jürgen Ehlers on the occasion of his 70th birthday. I have tried to find topics which were and are near to Jürgen's interests and scientific activities. I hope that the book – even in the era of electronic publishing – will serve for some time as a review of the themes treated; a source from which, for example, a PhD student could learn certain things thoroughly. In initiating the project of the book, the model I had in mind was the “Witten book”.

Early in his career Jürgen Ehlers worked on exact solutions, and demonstrated how one goes about characterizing exact solutions invariantly and searching for their intrinsic geometrical properties. So, it seems appropriate to begin the book with the article by J. Bičák: “Selected Solutions of Einstein's Field Equations: Their Role in General Relativity and Astrophysics.” Certainly not all of the large number of known exact solutions are of equal weight; this article describes the most important ones and explains their role for the development and understanding of Einstein's theory of gravity.

The second contribution is the article by H. Friedrich and A. Rendall: “The Cauchy Problem for the Einstein Equations”. It contains a careful exposition of the local theory, including the delicate gauge questions and a discussion of various ways of writing the equations as hyperbolic systems. Furthermore, it becomes clear that an understanding of the Cauchy problem really gives new insight into properties of the equations and the solutions and not just “uniqueness and existence”.

“Post-Newtonian Gravitational Radiation” is the title of the article by L. Blanchet. It deals with a topic Jürgen has contributed to and thought about deeply. However, these matters have developed in such a way that presently only a small number of experts understand all the technical details and subtleties. Hopefully, this present contribution will help us gain some understanding of certain aspects of post-Newtonian approximations.

The fourth contribution, “Duality and Hidden Symmetries in Gravitational Theories”, by D. Maison, outlines how far one of Jürgen's creations, the “Ehlers transformation” has evolved. From a “trick” to produce new solutions from known ones, the presence of such transformations in the space of solutions is now seen as a structural property of various gravitational theories, which at present attract a lot of attention.

The contribution, by R. Beig and B. Schmidt, “Time-Independent Gravitational Fields” collects and describes what is known about global properties of time-independent spacetimes. It contains, in particular, a fairly self-contained description of the multipole expansion at infinity.

V. Perlick has written on “Gravitational Lensing from a Geometric Viewpoint”. In the last ten years, lensing has become a fascinating new part of observational astrophysics. However, there are still important and interesting conceptual and mathematical questions when one tries to compare practical astrophysical applications with their mathematical modelling in Einstein’s theory of gravity. Some of those issues are treated in this contribution.

Obviously, there are some subjects missing, for which I was not able to find a contribution. What I regret most is that there is no article on cosmology, a field in which Jürgen has always been very interested.

An intriguing thought about the book is that Juergen would have read all these contributions before publication and no doubt improved them by his constructive criticism. For a short while I had in mind to ask Jürgen to do just this, but finally I decided that this would be too much of a burden for a birthday present.

Finally, I would like to thank the authors, friends and colleagues who have helped me and have given valuable advice.

Bernd Schmidt