

THE TENTH MARCEL GROSSMANN MEETING

On recent developments in theoretical and experimental
general relativity, gravitation, and relativistic field theories

Proceedings of the MG10 Meeting held at
The Brazilian Center of Physical Research (CBPF)
Rio de Janeiro, Brazil
20–26 July 2003

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World Scientific

Singapore · New Jersey · London · Hong Kong

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THE MARCEL GROSSMANN MEETINGS

The Marcel Grossmann Meetings were conceived with the aim of reviewing recent developments in gravitation and general relativity, with major emphasis on mathematical foundations and physical predictions. Their main objective is to bring together scientists from diverse backgrounds in order to deepen our understanding of spacetime structure and review the status of experiments testing Einstein's theory of gravitation.

Publications in the Series of Proceedings

Proceedings of the Tenth Marcel Grossmann Meeting on General Relativity

– these volumes

(Rio de Janeiro, Brazil, 2003) Edited by M. Novello, S. Perez-Bergliaffa, R. Ruffini
World Scientific, 2005

Proceedings of the Ninth Marcel Grossmann Meeting on General Relativity

(Rome, Italy, 2000) Edited by V.G. Gurzadyan, R.T. Jantzen, R. Ruffini
World Scientific, 2002

Proceedings of the Eighth Marcel Grossmann Meeting on General Relativity

(Jerusalem, Israel, 1997) Edited by T. Piran
World Scientific, 1998

Proceedings of the Seventh Marcel Grossmann Meeting on General Relativity

(Stanford, USA, 1994) Edited by R.T. Jantzen and G.M. Keiser
World Scientific, 1996

Proceedings of the Sixth Marcel Grossmann Meeting on General Relativity

(Kyoto, Japan, 1991) Edited by H. Sato and T. Nakamura
World Scientific, 1992

Proceedings of the Fifth Marcel Grossmann Meeting on General Relativity

(Perth, Australia, 1988) Edited by D.G. Blair and M.J. Buckingham
World Scientific, 1989

Proceedings of the Fourth Marcel Grossmann Meeting on General Relativity

(Rome, Italy, 1985) Edited by R. Ruffini
World Scientific, 1986

Proceedings of the Third Marcel Grossmann Meeting on General Relativity

(Shanghai, People's Republic of China, 1982) Edited by Hu Ning
Science Press – Beijing and North-Holland Publishing Company, 1983

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Proceedings of the Second Marcel Grossmann Meeting on General Relativity
(Trieste, Italy, 1979) Edited by R. Ruffini
North-Holland Publishing Company, 1982

Proceedings of the First Marcel Grossmann Meeting on General Relativity
(Trieste, Italy, 1976) Edited by R. Ruffini
North-Holland Publishing Company, 1977

Series Editor: REMO RUFFINI

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* Edward Kolb of Fermilab deserves special thanks
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These proceedings would not have been possible without the upload robot designed by Stefano Cazzella or without the wide range of technical support provided by ICRA system managers Vittorio Vannini and Maurizio Cosma. Many thanks also to Vahe Gurzadyan.

ACKNOWLEDGEMENTS

We would like to thank the Military Institute of Engineering (IME) and the Federal University of the State of Rio de Janeiro (UNIRIO) for facilitating the use of rooms for the plenary and some parallel sessions of the meeting. Thanks also to the Secretary of Science and Technology of the City of Rio de Janeiro, to the Secretary of Science and Technology of the State of Rio de Janeiro, and to the Executive Secretary of the Ministry of Science and Technology, Luiz Fernandes, for his constant support to the activities of ICRA-BR. The editors would like to thank Bob Jantzen for his help during all stages of the editing of these proceedings.

MARCEL GROSSMANN AWARDS

TENTH MARCEL GROSSMANN MEETING

Institutional Award

CBPF

(Brazilian Center for Research in Physics)

*“for its role as a teaching and research institution
and as a place originating fundamental physics ideas
in the exploration of the universe”*

—presented to its founders Cesar Lattes, José Leite Lopes and Jayme Tiomno

Individual Awards

Yvonne Choquet-Bruhat and James W. York, Jr.

*“for separate as well as joint work in establishing the mathematical framework
for proving the existence and uniqueness of solutions to
Einstein’s gravitational field equations”*

Yuval Ne’eman

*“for his contributions to science, epistimology, mathematics and physics
from subnuclear to space sciences”*

Each recipient is presented with a silver casting of the TEST sculpture by the artist A. Pierelli. The original casting was presented to His Holiness Pope John Paul II on the first occasion of the Marcel Grossmann Awards.

FOURTH MARCEL GROSSMANN MEETING

Institutional Award

THE VATICAN OBSERVATORY

Individual Awards

WILLIAM FAIRBANK, ABDUS SALAM

FIFTH MARCEL GROSSMANN MEETING

Institutional Award

THE UNIVERSITY OF WESTERN AUSTRALIA

Individual Awards

SATIO HAYAKAWA, JOHN ARCHIBALD WHEELER

SIXTH MARCEL GROSSMANN MEETING

Institutional Award

RESEARCH INSTITUTE FOR THEORETICAL PHYSICS (Hiroshima)

Individual Awards

MINORU ODA, STEPHEN HAWKING

SEVENTH MARCEL GROSSMANN MEETING

Institutional Award

THE HUBBLE SPACE TELESCOPE INSTITUTE

Individual Awards

SUBRAHMANYAN CHANDRASEKHAR, JIM WILSON

EIGHTH MARCEL GROSSMANN MEETING

Institutional Award

THE HEBREW UNIVERSITY OF JERUSALEM

Individual Awards

TULLIO REGGE, FRANCIS EVERITT

NINTH MARCEL GROSSMANN MEETING

Institutional Award

THE SOLVAY INSTITUTES

Individual Awards

RICCARDO GIACCONI, ROGER PENROSE

C. Lattes and J. Tiomno

J. Leite Lopes and J. Tiomno

Jayme Tiomno, John Wheeler and Remo Ruffini (Princeton, 2002)

TEST: sculpture by A. Pierelli.

Yuval Ne'eman

Y. Choquet-Bruhat

J. York.

PREFACE

In 1975 the Marcel Grossmann Meetings were established by Remo Ruffini and Abdus Salam to provide a forum that would meet every three years to discuss recent advances in gravitation, general relativity and relativistic field theories, emphasizing their mathematical foundations, physical predictions and experimental tests. These meetings aim to facilitate the exchange of ideas among scientists, to deepen our understanding of space-time structures and to review the status of ongoing experiments and observations testing Einstein's theory of gravitation either from ground or space-based experiments.

The first two Marcel Grossmann Meetings MG1 and MG2 were held in Trieste (1975, 1979). The meetings have since grown under the guidance of its International Organizing Committee and eventually of a large International Coordinating Committee. MG3 (1982) took place in Shanghai and distinguished itself as the first truly international scientific meeting to take place in China after the so-called cultural revolution. The range of topics presented at these meetings has gradually broadened to accommodate issues of major scientific interest. For example, the birth of "astroparticle physics" was testified to in the inaugural lecture of Abdus Salam at MG4 in Rome (1985), which saw entire sessions dedicated to this new topic. The proceedings of these first four meetings were published by North Holland in Amsterdam. Starting with MG5 held in Perth (1988), they have been published by World Scientific in Singapore.

General relativistic theories have become more and more the theoretical foundation for a very broad new area of research encompassing experiments and observations which make use of techniques from space missions in the optical, X- and gamma-ray wavelengths to large radio and optical ground-based observatories as well as underground laboratories. The enormous momentum gained following very large investments in observational techniques, having no precedent in other areas of science, has gradually led to the maturing of a new field of research: relativistic astrophysics. Paradoxically Einstein's theory, born as a purely theoretical and mathematical conceptual revolution with extremely feeble supporting experimental evidence, has become the driving force in the theoretical understanding of possibly the largest observational and experimental scientific effort in the history of mankind. The Marcel Grossmann meetings have followed these developments at MG6 (Kyoto, 1991), MG7 (Stanford, 1994), MG8 (Jerusalem, 1997) and MG9, or 'MG IX MM' to emphasize the millennium change (Rome 2000), which has become an important point of reference for this field.

The Tenth Marcel Grossmann Meeting (MG10) was held from July 20–26, 2003 in Rio de Janeiro. MG10 was organized by the International Organizing Committee composed of D. Blair, Y. Choquet-Bruhat, D. Christodoulou, T. Damour, J. Ehlers, F. Everitt, Fang Li Zhi, S. Hawking, Y. Ne'eman, R. Ruffini (chair), H. Sato, R. Sunyaev, and S. Weinberg. Essential to its planning was the International

Coordinating Committee of 135 members from scientific institutions of 54 countries and the work of the Local Program Committee. The morning plenary sessions took place in the auditorium of the Military Institute of Engineering (IME), located on a beautiful spot just below the famous Sugar Loaf mountain in the Urca neighborhood of Rio. The afternoon parallel sessions took place at the Brazilian Center of Physical Research (CBPF) and at the University of Rio de Janeiro (UNIRIO).

The opening ceremony was held the morning of July 21. The importance of the conference attracted the attention of the Brazilian government. During this opening ceremony Professor Roberto Amaral, the Minister of Science and Technology of Brazil, announced the creation of a new institute in Rio de Janeiro devoted to cosmology, relativity and astrophysics: the ICRA-BR, which will be a member of ICRA-Net. His speech is reproduced in these proceedings. Other welcoming addresses were given by Remo Ruffini (Chairman of the International Organizing Committee) followed by Mario Novello, Fernando Peregrino, Luis Pinguelli Rosa, Maraco Vales, and Enio Candiotti.

Following tradition, the Marcel Grossmann Awards were also announced in this opening session. The institutional award was given to the CBPF (Brazilian Center for Research in Physics) for its role as a teaching and research institution and as a place originating fundamental physics ideas in the exploration of the universe, and was presented to CBPF founders Cesar Lattes, José Leite Lopez and Jayme Tiomno (see photos on page xi). Unfortunately Professor Lattes was not present at the ceremony due to health problems and was represented by Alfredo Marques. The individual award was shared by Yvonne Choquet-Bruhat and James W. York, Jr. (see photos on page xiii), for separate as well as joint work in establishing the mathematical framework for proving the existence and uniqueness of solutions to Einstein's gravitational field equations. Professor York received his award in Rio and presented a lecture at the meeting, while Professor Choquet-Bruhat received her award at a later ceremony at the Institut Hautes Etudes Scientifiques in Paris. The other individual award went to Yuval Ne'eman for his contributions to science, epistemology, mathematics and physics from subnuclear to space sciences (see photo on page xiii). Each of them received a silver replica of the TEST (Traction of Events in Space-Time) sculpture by Attilio Pierelli.

After the opening ceremony, the meeting began with a talk by Yuval Ne'eman entitled "Mathematics, Physics and Ping-Pong". The scientific program included 29 morning plenary talks during 6 days, and 57 parallel sessions over five afternoons, during which roughly 500 papers were presented.

The 500 scientists and their families from 52 countries present at the meeting had the opportunity to enjoy the beauty of the city of Rio de Janeiro, along with summer-like clear-sky weather, which enhanced the views of the city. During the afternoon of June 23, some of the participants visited the Corcovado mountain with its world famous statue, while others took a jeep tour to the Tijuca forest, the greatest urban forest in the world. The closing banquet took place on the evening

of June 25 at a typical Brazilian restaurant with a breathtaking view of the Sugar Loaf and the Botafogo Bay, and participants enjoyed traditional Brazilian music after the meal.

In the closing speech on June 26, Remo Ruffini and Mario Novello thanked the members of the Organizing and Coordinating Committees for their continuing efforts and CNPq, MCT, FAPERJ, FINEP, IUPAP, UNESCO, and ICTP for the financial support which led to the success of a forum on such a grand scale.

The three volumes of these proceedings represent an authoritative view of relativistic astrophysics, a field which is now becoming one of the priorities in the scientific endeavour. The first volume includes the plenary talks and parallel session review talks, while the last two volumes include the remaining contributions to the parallel sessions. The papers that appear in these volumes cover all aspects of gravitation, from mathematical issues to recent observations and experiments, summarizing a complete picture of our current understanding of gravitational theories.

Cesar Lattes at Chacaltaya Cosmic Physics Laboratory.

R. Feynman in Rio

Inaugural Address

Dear meeting participants, having been honored with the invitation to take part in the opening ceremony for this conference, I found myself in an awkward dilemma: to accept it or to travel abroad to attend to State matters that had been previously arranged for the same date . . .

The reasons leading me along the path that has brought me to this solemn occasion are three.

The first one derives from the purpose of sharing with Brazilian physicists the honor of having our country appointed to host a meeting of such meaning and magnitude, which is for the first time being held in the southern hemisphere.

And this is because this choice could have had no other motive than the representativeness and qualification of the Brazilian community of cosmologists, astrophysicists and relativist physicists, whom, on behalf of the government and the Ministry of Science and Technology, I now compliment—especially the relentless local organizer of this event, distinguished Professor Mario Novello.

I fully recognize how important this is, for I know very well that the opportunity for these research areas in an emerging country like Brazil, set within these sad tropics, has been denied for a great many years under the pretext that it would be more appropriate to invest in less abstract fields whose work could produce more direct and palpable effects for our development . . .

Since the objective of physics is to describe everything, its field of investigation must have no boundaries, especially those determined by a narrow view of nature, the role and the purpose of science. If in the end, physicists are to find a singularity or an eternal and borderless universe, if they are to decipher what Stephen Hawking calls the mind of God, or demonstrate its wave function, or eventually develop an equation that can explain the creation of order and complexity starting from chaos, only time will tell. Until then physicists and researchers, who have already reinvented time and space and have discovered how vacuum may be the source of astonishing energies, who have explained how the infinitely big has been condensed into the infinitely small, will continue trying to decipher all the profoundness of the universe's riches. And as they discover black holes and the mysteries of gravitation, time travel and the tissue of reality, they develop new mathematical formalisms, unveil new secrets and principles, and eventually raise endless possibilities in the field of physics and also in the immediate applications of science . . .

The second reason for my being here now is connected with the desire to reassure such a representative audience that basic science is to go on being treated as the source of knowledge, experience and qualification, without which no policy for the applied fields and the innovation of industrial products and processes will ever bear the expected fruit.

Dear meeting participants, this new outlook on science and technology is part of a management model inspired by changes of attitude and by policies that are much

broader because they are derived from a new outlook on the world and a new project for society. A government of changes in which I am honored to participate, President Luiz Inacio Lula da Silva's administration is committed to profound changes that will lead not only to the development of the country but also to the democratization of its fruit. This is the equivalent of upholding the need to massively invest in education, science and technology and at the same time, to democratize the fruit of development and the fruit of every single accomplishment of ours . . .

The third reason that has brought me to this event is connected with the pleasure of personally announcing a Federal Government decision, therefore a Ministry of Science and Technology decision, related to creating in Rio de Janeiro another international center of relativistic astrophysics, with sponsorship from ICRA and support from UNESCO, an institution with which we maintain close and fruitful cooperation.

It is an effort we deem most relevant not only for cosmology and astrophysics but also for the development of Brazilian science, to which it will certainly become a reference point . . .

I am sure that Brazilian science will benefit a lot from this conference, and I am happy because my Ministry's Brazilian Center for Physical Research, the CBPF, is hosting it.

But above all, I would like to speak of my pride as a Brazilian and as the State Minister for Science and Technology in Brazil when I learned that the organizing committee for this Tenth Marcel Grossmann Meeting decided to grant the institutional Marcel Grossmann Award to CBPF, a most distinguished research unit within this Ministry and in the entire country, with the quote "for your efforts as a teaching and research institution and as a place that has issued key physical ideas for the exploration of the universe."

Professor Remo Ruffini, this pledge of confidence in Brazilian science by ICRA, as head of which you made your best efforts, is not in vain, because the Ministry of Science and Technology will do its utmost to bring to the hands of Brazilian physicists the instruments they need to comply with such a distinguished honor. This very same morning I shall meet with Professor Ruffini and Professor Mario Novello in order to draw the preliminary lines that shall guide our mutual responsibilities to carry out this project.

On behalf of the Brazilian government and people, I wish all the distinguished scientists here a most productive and fruitful meeting, in the hope that new scientific cooperation and integration programs be celebrated and that moments of most agreeable companionship be shared in this wonderful city of Rio de Janeiro.

Thank you very much.

Roberto Amaral
Minister of Science and Technology
Brazil

Opening of the Tenth Marcel Grossmann Meeting.
From left to right: F. Peregrino, R. Ruffini, M. Novello,
R. Amaral, L. Pinguelli Rosa, M. Vales, and E. Candiotti