

THE THIRTEENTH MARCEL GROSSMANN MEETING

**On Recent Developments in Theoretical and Experimental
General Relativity, Astrophysics and Relativistic Field Theories**

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**On Recent Developments in Theoretical and Experimental
General Relativity, Astrophysics and Relativistic Field Theories**

Proceedings of the MG13 Meeting
on General Relativity

Stockholm University, Stockholm, Sweden

1–7 July 2012

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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.

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The Marcel Grossman Meetings were founded with the premise that scientists of all nations have a right to meet to exchange knowledge independent of national borders. As such we affirm the IUPAP declaration: "To secure IUPAP sponsorship, the organisers have provided assurance that MG13 will be conducted in accordance with IUPAP principles as stated in the IUPAP resolution passed by the General Assembly in 2008. In particular, no bona fide scientist will be excluded from participation on the grounds of national origin, nationality, or political considerations unrelated to science."

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The photos which precede or follow the parallel session titlepages in volumes B and C were taken during the meeting by the photographer Andrea Buccella.

DEDICATION to Fang Li-Zhi 1936–2012

These proceedings are dedicated to the memory of Fang Li-Zhi who in addition to standing up for the principle of freedom of thought and expression, worked tirelessly for the International Organizing Committee of all the Marcel Grossmann Meetings since MG3 in 1982, the first scientific meeting held in China open to all scientists from every nation.



Fang Li-Zhi with Remo Ruffini



Remo Ruffini and Fang Li-Zhi with Humitako Sato (center) at MG6 in Kyoto in 1991 with friends Leopold Halpern (far right) and Robert Jantzen (far left).



Fang Li-Zhi and wife Shuxian Li meeting Pope John Paul II.

MARCEL GROSSMANN AWARDS

THIRTEENTH MARCEL GROSSMANN MEETING

Institutional Award

AlbaNova University Center

“for its innovative status as a joint institute established by Stockholm University and the Royal Institute of Technology and for fostering contributions to cosmology and astrophysics in the profound scientific tradition established by Oskar Klein.”

— presented to the Rector of Stockholm University, Prof. Kåre Bremer

Individual Awards

David Arnett

“for exploring the nuclear physics and yet unsolved problems of the endpoint of thermonuclear evolution of stars, leading to new avenues of research in physics and astrophysics.”

Vladimir Belinski and Isaak M. Khalatnikov

“for the discovery of a general solution of the Einstein equations with a cosmological singularity of an oscillatory chaotic character known as the BKL singularity.”

Filippo Frontera

“for guiding the Gamma-ray Burst Monitor Project on board the BeppoSAX satellite, which led to the discovery of GRB X-ray afterglows, and to their optical identification.”

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.

TWELFTH MARCEL GROSSMANN MEETING**Institutional Award**

INSTITUT DES HAUTES ÉTUDES SCIENTIFIQUE (IHES)

Individual Awards

JAAN EINASTO, CHRISTINE JONES, MICHAEL KRAMER

ELEVENTH MARCEL GROSSMANN MEETING**Institutional Award**

FREIE UNIVERSITÄT BERLIN

Individual Awards

ROY KERR, GEORGE COYNE, JOACHIM TRÜMPER

TENTH MARCEL GROSSMANN MEETING**Institutional Award**

CBPF (BRAZILIAN CENTER FOR RESEARCH IN PHYSICS)

Individual Awards

YVONNE CHOQUET-BRUHAT, JAMES W. YORK, JR., YUVAL NE'EMAN

NINTH MARCEL GROSSMANN MEETING**Institutional Award**

THE SOLVAY INSTITUTES

Individual Awards

RICCARDO GIACCONI, ROGER PENROSE, CECILE and BRYCE DEWITT

EIGHTH MARCEL GROSSMANN MEETING**Institutional Award**

THE HEBREW UNIVERSITY OF JERUSALEM

Individual Awards

TULLIO REGGE, FRANCIS EVERITT

SEVENTH MARCEL GROSSMANN MEETING**Institutional Award**

THE HUBBLE SPACE TELESCOPE INSTITUTE

Individual Awards

SUBRAHMANYAN CHANDRASEKHAR, JIM WILSON

SIXTH MARCEL GROSSMANN MEETING

Institutional Award

RESEARCH INSTITUTE FOR THEORETICAL PHYSICS (Hiroshima)

Individual Awards

MINORU ODA, STEPHEN HAWKING

FIFTH MARCEL GROSSMANN MEETING

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THE UNIVERSITY OF WESTERN AUSTRALIA

Individual Awards

SATIO HAYAKAWA, JOHN ARCHIBALD WHEELER

FOURTH MARCEL GROSSMANN MEETING

Institutional Award

THE VATICAN OBSERVATORY

Individual Awards

WILLIAM FAIRBANK, ABDUS SALAM



TEST: sculpture by Attilio Pierelli



AlbaNova University Center

Fig. 1. Recipient of the Marcel Grossmann Institutional Award for “its innovative status as a joint institute established by Stockholm University and the Royal Institute of Technology and for fostering contributions to cosmology and astrophysics in the profound scientific tradition established by Oskar Klein.” The AlbaNova University Center was founded in 2010 jointly by Stockholm University and the Royal Institute of Technology. It houses departments from the two founding universities in the fields of physics, astronomy and biotechnology. With its open and gentle architectural qualities, the center serves as an appreciated workplace for scientists and students in the more than 40 research groups and education departments within the center. The wide scope of research at AlbaNova has contributed to an excellent atmosphere for interdisciplinary communications and collaborations. In the fields of cosmology, astronomy and fundamental physics, a good example is provided by the success of the multi-departmental Oskar Klein Center, established within the AlbaNova environment.



David Arnett

Fig. 2. Recipient of the Marcel Grossmann Award “for exploring the nuclear physics and yet unsolved problems of the endpoint of thermonuclear evolution of stars, leading to new avenues of research in physics and astrophysics.”



Vladimir Belinski

Fig. 3. Joint recipient of the Marcel Grossmann Individual Award “for the discovery of a general solution of the Einstein equations with a cosmological singularity of an oscillatory chaotic character known as the BKL singularity.”



Isaak M. Khalatnikov

Fig. 4. Joint Recipient of the Marcel Grossmann Individual Award “for the discovery of a general solution of the Einstein equations with a cosmological singularity of an oscillatory chaotic character known as the BKL singularity.”



Filippo Frontera

Fig. 5. Recipient of the Marcel Grossmann Individual Award “for guiding the Gamma-ray Burst Monitor Project on board the BeppoSAX satellite, which led to the discovery of GRB X-ray afterglows, and to their optical identification.”

PREFACE

The Thirteenth Marcel Grossmann Meeting (MG13) marked one hundred years since the collaboration of Marcel Grossmann and Albert Einstein. The meeting took place July 1–7 at Stockholm University in Stockholm, Sweden just following the summer solstice with delightfully long days of extended daylight.

The morning plenary sessions of the meeting were held at the magnificent Aula Magna Hall at the main campus, conveniently served by a nearby Metro stop of the city's efficient transportation system, while lunch and the afternoon parallel sessions were held in the comfortable AlbaNova University Center 15 minutes walk back towards the city center, and 10 minutes walk from the next Metro stop. Half hour coffee breaks in the morning and afternoon facilitated personal exchanges among the many participants.

The 870 registered participants of MG13 enjoyed a comfortable sunny week of mild temperatures after a month of almost steady rain preceding the meeting, which turned out to be another successful gathering of a large and diverse group of scientists this time coming from 59 different countries, feedback from whom was extremely positive, marking this meeting as the most scientifically successful one of the series in recent memory, both for its scientific program and the organizational details that made it function well.

The meeting began on Monday, July 1 with a welcoming address by the Rector of Stockholm University, Prof. Kåre Bremer, who then accepted the institutional award on behalf of the AlbaNova University Center in the following Marcel Grossmann Awards ceremony. The individual awards were given jointly to Vladimir Belinski and Isaak M. Khalatnikov, and then to Filippo Frontera, and later on Wednesday morning to David Arnett, who had been unavoidably delayed by transportation problems. Each recipient was presented with a silver casting of the TEST sculpture by the artist Attilio Pierelli.

The meeting banquet was held Wednesday evening at a facility in Skansen Park overlooking the city from across the water with roughly 570 enthusiastic diners, during which brief remarks by Tsvi Piran commemorated the seventieth birthday of Remo Ruffini. This event was preceded the evening before by a marvelous cocktail reception generously offered to an even greater number of meeting participants by City Hall in the impressive location and ambiance of the Nobel Prize Awards dinner.

Interesting evening public lectures were given in the Aula Magna Hall Monday evening by Mario Livio: "The greatest scientific achievements of the Hubble space telescope," and Friday evening by Carlos Frenk: "Everything from nothing: how our universe was made," while Thursday evening was devoted to remembrances of Fang Li-Zhi and his role in relativistic astrophysics.

The main scientific program included six mornings (from Monday to Saturday) comprising 33 plenary talks and four afternoons of roughly 75 parallel sessions. Following the spirit that led to the inception of the Marcel Grossmann meetings, the plenary program gave an authoritative review of a wide range of timely topics rang-

ing from formal mathematical approaches to experimental results probing spacetime structure, and covered most recent developments in theoretical, experimental and observational aspects of the physics and astrophysics of relativistic gravity. The complementary parallel sessions allowed many researchers to present their latest work, and to be informed of recent advances in the many sub-fields related to the physics of relativistic gravity. The plenary talks were the following:

Hermann Nicolai (Max-Planck-Institut für Gravitationsphysik): Hidden symmetries: from BKL to Kac-Moody

Claes Uggla (Karlstad University): Spacetime singularities: recent developments

Sergiu Klainerman (Princeton University): Recent developments in mathematical GR

Harvey Reall (Centre for Mathematical Sciences, Cambridge): Black holes in higher dimensions

Jan Ambjorn (Copenhagen University): Lattice gravity: overview and recent progress

Petr Horava (Berkeley Center for Theoretical Physics): Gravity with anisotropic scaling and the multicritical universe

Martin Reuter (Johannes-Gutenberg-Universität): QEG: Towards an asymptotically safe quantum theory of gravity

Zvi Bern (UCLA): Perturbative quantum gravity as a double copy of gauge theory and implication for UV properties

Ariel Goobar (Stockholm University): Supernova cosmology: past and future

Robert Kirshner (Harvard University): The accelerating universe: a Nobel surprise

David Arnett (University of Arizona): Stellar turbulence and why we should care

Jorge Rueda (ICRANet and University of Rome, la Sapienza): Strong, weak, electromagnetic and gravitational interactions in neutron stars

Luciano Rezzolla (Albert Einstein Institute): Using numerical relativity to explore fundamental physics and astrophysics

David Reitze (California Institute of Technology): Ground-based gravitational-wave astronomy using interferometers: past and future

Tsvi Piran (The Hebrew University): Electromagnetic signals from neutron star mergers

Bing Zhang (University of Nevada): Open questions in GRB physics

Remo Ruffini (University of Rome, la Sapienza): GRBs and the supernova-neutron-star-black-hole sequence

Michael Kramer (University of Manchester): Precision tests of theories of gravity using pulsars

Piero Madau (University of California Santa Cruz): Connecting the dark and light side of galaxy formation

Charles Bennett (Johns Hopkins University): WMAP

Nazzareno Mandolesi (INAF IASF Bologna): Planck and fundamental physics

Jean-Loup Puget (Académie des Sciences): High energy Planck Mission

Sunyaev Rashid (Max-Planck-Institut für Astrophysik and IKI, Moscow): Unavoidable CMB spectral features and black body photosphere of our universe

John Carlstrom (KAVLI Institute for Cosmological Physics): Cosmology with the thermal and kinetic Sunyaev-Zel'dovich effects

David Spergel (Princeton University): The cosmic microwave background and the hidden universe

Roy Kerr (University of Canterbury): The Kerr metric 50 years later

Francis Everitt (Stanford University): Space as the testing ground for fundamental physics

Paolo De Bernardis (University of Rome, la Sapienza): Frontiers of cosmic microwave background research

Chiara Mariotti (INFN Torino and CERN): Recent searches of the Standard Model Higgs within CMS

Domizia Orestano (University of Rome 3): Search for the Standard Model Higgs with the ATLAS detector

Luciano Maiani: LHC high-lights

The final three talks followed the official release of the CERN team announcement of the probable discovery of the Higgs particle only hours before at the 36th International Conference on High Energy Physics (ICHEP) in Melbourne, Australia, giving the audience a first hand account of the work leading to this result. The meeting was closed at noon on Saturday, July 7, with concluding remarks by Remo Ruffini.

These three volumes represent the proceedings of the meeting. The first volume contains articles by the individual Marcel Grossmann Awardees followed by the contributions of the plenary speakers together with review articles from some of the parallel sessions, including the first in depth study of the role of Marcel Grossman in the development of general relativity. The second and third volumes contain the contributions from the parallel sessions. The third volume includes a participant list and the author index. Most of the plenary and review articles which appear here were also published as regular articles in the *International Journal of Modern Physics D* during the years 2012–2014. The three volumes of proceedings are printed in black and white, but some of the articles have color figures. The readers may refer to the publisher's website (<http://www.worldscientific.com/>) for the electronic version which is in color.

CONTENTS

Publications in this Series	v
Sponsors	vii
Organizing Committees and Acknowledgements	viii
Dedication	x
Marcel Grossmann Awards	xii
Preface	xx

PART A

PLENARY TALKS

On the Cosmological Singularity <i>Belinski, Vladimir A.</i>	3
GRB Afterglow Discovery with Bepposax: Its Story 15 Years Later <i>Frontera, Filippo</i>	33
Rotation, Convection, and Core Collapse <i>Arnett, W. David</i>	54
Spacetime Singularities: Recent Developments <i>Uggla, Claes</i>	59
Hidden Symmetries: From BKL to Kac-Moody <i>Fleig, Philipp; Nicolai, Hermann</i>	80
Recent Results in Mathematical GR <i>Klainerman, Sergiu</i>	93
Higher Dimensional Black Holes <i>Reall, Harvey S.</i>	105
Causal Dynamical Triangulations and the Search for a Theory of Quantum Gravity <i>Ambjorn, Jan; Görlich, Andrzej; Jurkiewicz, Jerzy; Loll, Renate</i>	120
On Quantum Gravity, Asymptotic Safety, and Paramagnetic Dominance <i>Nink, Andreas; Reuter, Martin</i>	138
Perturbative Quantum Gravity as a Double Copy of Gauge Theory and Implication for UV Properties <i>Bern, Zvi</i>	158