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# Gyros, Clocks, Interferometers...: Testing Relativistic Gravity in Space



Springer

# Gyros Clocks Interferometers Testing Relativistic Gravity In Space Lecture Notes In Physics

**Hansjörg Dittus, Claus  
Lämmerzahl, Slava G. Turyshev**



## **Gyros Clocks Interferometers Testing Relativistic Gravity In Space Lecture Notes In Physics:**

*Gyros, Clocks, Interferometers....: Testing Relativistic Gravity in Space* C. Lämmerzahl, C.W.F. Everitt, F.W.

Hehl, 2007-09-04 Many new tests of gravity and in particular of Einstein's general relativity theory will be carried out in the near future The Lense Thirring effect and the equivalence principle will be tested in space moreover gravitational waves will be detected and new atomic interferometers and clocks will be built for measurements in gravitational and inertial fields New high precision devices have made these experiments feasible They will contribute to a better understanding of gravitational physics Both experimental developments and the theoretical concepts are collected in this volume Exhaustive reviews give an overall insight into the subject of experimental gravitation

**Gyros, Clocks, Interferometers....: Testing Relativistic Gravity in Space** C. Lämmerzahl, C.W.F. Everitt, F.W. Hehl, 2001-03-13 Many new tests of gravity and in particular of Einstein's general relativity theory will be carried out in the near future The Lense Thirring effect and the equivalence principle will be tested in space moreover gravitational waves will be detected and new atomic interferometers and clocks will be built for measurements in gravitational and inertial fields New high precision devices have made these experiments feasible They will contribute to a better understanding of gravitational physics Both experimental developments and the theoretical concepts are collected in this volume Exhaustive reviews give an overall insight into the subject of experimental gravitation

**Relativistic Celestial Mechanics of the Solar System** Sergei Kopeikin, Michael Efroimsky, George Kaplan, 2011-10-25 This authoritative book presents the theoretical development of gravitational physics as it applies to the dynamics of celestial bodies and the analysis of precise astronomical observations In so doing it fills the need for a textbook that teaches modern dynamical astronomy with a strong emphasis on the relativistic aspects of the subject produced by the curved geometry of four dimensional spacetime The first three chapters review the fundamental principles of celestial mechanics and of special and general relativity This background material forms the basis for understanding relativistic reference frames the celestial mechanics of N body systems and high precision astrometry navigation and geodesy which are then treated in the following five chapters The final chapter provides an overview of the new field of applied relativity based on recent recommendations from the International Astronomical Union The book is suitable for teaching advanced undergraduate honors programs and graduate courses while equally serving as a reference for professional research scientists working in relativity and dynamical astronomy The authors bring their extensive theoretical and practical experience to the subject Sergei Kopeikin is a professor at the University of Missouri while Michael Efroimsky and George Kaplan work at the United States Naval Observatory one of the world's premier institutions for expertise in astrometry celestial mechanics and timekeeping

**Relativity in Fundamental Astronomy (IAU S261)** International Astronomical Union. Symposium, 2010-01-28 IAU S261 summarizes the present state of applied relativity and discusses the applications and future tests of general relativity

Atom Optics and Space Physics E. Arimondo, W. Ertmer, Wolfgang Schleich, E. M.

Rasel, 2009 The goal of this volume is to discuss the rapidly moving field of atom optics and interferometry with all its intricate aspects ranging from fundamental physics to applications and the theory of relativity The breathtaking success in manipulating atoms using lasers has encouraged these two so far disjunct communities to move closer together and begin collaborations After an introduction to atom optics and Bose Einstein condensation the theoretical foundations of cold atom interferometers their use to test gravity and their implementation in laboratory measurements of the Earth rotation and of Newton's gravitational constant are discussed Several papers discuss the characteristics of gyroscopes and interferometers as sensors for inertial forces starting from gyroscopes based on light waves and comparing their sensitivity to those based on matter waves The final topic is the variation of fundamental constants a subject that during the last years has attracted a lot of attention from different communities of physics

**Earth Gravity Field from Space - from Sensors to Earth Sciences**

G. Beutler, M.R. Drinkwater, R. Rummel, Rudolf von Steiger, 2013-04-18 Volume resulting from an ISSI Workshop 11-15 March 2002 Bern Switzerland

**2001, a Relativistic Spacetime Odyssey**

Ignazio Ciufolini, Daniele Dominici, L. Lusanna, 2003

This volume offers a comprehensive overview of our understanding of gravity at both the experimental and the theoretical level Critical reviews by experts cover topics ranging from astrophysics anisotropies in the cosmic microwave background gamma ray bursts neutron stars and astroparticles cosmology the status of gravitational wave sources and detectors verification of Newton's law at short distances the equivalence principle gravito magnetism measurement theory time machines and the foundations of Einstein's theory to string theory and loop quantum gravity

**2001: A Relativistic Spacetime Odyssey: Experiments And Theoretical Viewpoints On General Relativity And Quantum Gravity - Proceedings Of The 25th Johns Hopkins Workshop On Current Problems In Particle Theory**

Ignazio Ciufolini, Daniele Dominici, Luca Lusanna, 2003-01-16

This volume offers a comprehensive overview of our understanding of gravity at both the experimental and the theoretical level Critical reviews by experts cover topics ranging from astrophysics anisotropies in the cosmic microwave background gamma ray bursts neutron stars and astroparticles cosmology the status of gravitational wave sources and detectors verification of Newton's law at short distances the equivalence principle gravito magnetism measurement theory time machines and the foundations of Einstein's theory to string theory and loop quantum gravity

*Quantum Electrodynamics: Atoms, Lasers And Gravity* Ulrich D Jentschura, Gregory S Adkins, 2022-05-30 This book introduces readers to a variety of topics surrounding quantum field theory notably its role in bound states laser physics and the gravitational coupling of Dirac particles It discusses some rather sophisticated concepts based on detailed derivations which cannot be found elsewhere in the literature It is suitable for undergraduates graduates and researchers working on general relativity relativistic atomic physics quantum electrodynamics as well as theoretical laser physics

General Relativity, Cosmology and Astrophysics

Jiří Bičák, Tomáš Ledvinka, 2014-06-12 The articles included in this Volume represent a broad and highly qualified view on the present state of general relativity quantum gravity and their cosmological and

astrophysical implications As such it may serve as a valuable source of knowledge and inspiration for experts in these fields as well as an advanced source of information for young researchers The occasion to gather together so many leading experts in the field was to celebrate the centenary of Einstein's stay in Prague in 1911-1912 It was in fact during his stay in Prague that Einstein started in earnest to develop his ideas about general relativity that fully developed in his paper in 1915 Approaching soon the centenary of his famous paper this volume offers a precious overview of the path done by the scientific community in this intriguing and vibrant field in the last century defining the challenges of the next 100 years The content is divided into four broad parts i Gravity and Prague ii Classical General Relativity iii Cosmology and Quantum Gravity and iv Numerical Relativity and Relativistic Astrophysics

*From Quantum To Cosmos: Fundamental Physics Research In Space* Slava G Turyshev, 2009-05-21 Space based laboratory research in fundamental physics is an emerging research discipline that offers great discovery potential and at the same time could drive the development of technological advances which are likely to be important to scientists and technologists in many other different research fields The articles in this review volume have been contributed by participants of the international workshop From Quantum to Cosmos Fundamental Physics Research in Space held at the Airlie Center in Warrenton Virginia USA on May 21-24 2006 This unique volume discusses the advances in our understanding of fundamental physics that are anticipated in the near future and evaluates the discovery potential of a number of recently proposed space based gravitational experiments Specific research areas covered include various tests of general relativity and alternative theories search of physics beyond the Standard Model investigations of possible violations of the equivalence principle search for new hypothetical long and short range forces variations of fundamental constants tests of Lorentz invariance and attempts at unification of the fundamental interactions The book also encompasses experiments aimed at the discovery of novel phenomena including dark matter candidates and studies of dark energy

**Springer Handbook of Spacetime** Abhay Ashtekar, Vesselin Petkov, 2014-09-01 The Springer Handbook of Spacetime is dedicated to the ground breaking paradigm shifts embodied in the two relativity theories and describes in detail the profound reshaping of physical sciences they ushered in It includes in a single volume chapters on foundations on the underlying mathematics on physical and astrophysical implications experimental evidence and cosmological predictions as well as chapters on efforts to unify general relativity and quantum physics The Handbook can be used as a desk reference by researchers in a wide variety of fields not only by specialists in relativity but also by researchers in related areas that either grew out of or are deeply influenced by the two relativity theories cosmology astronomy and astrophysics high energy physics quantum field theory mathematics and philosophy of science It should also serve as a valuable resource for graduate students and young researchers entering these areas and for instructors who teach courses on these subjects The Handbook is divided into six parts Part A Introduction to Spacetime Structure Part B Foundational Issues Part C Spacetime Structure and Mathematics Part D Confronting Relativity theories with observations Part E General relativity and the universe Part F

Spacetime beyond Einstein     Inertia and Gravitation Herbert Pfister, Markus King, 2015-02-24 This book focuses on the phenomena of inertia and gravitation one objective being to shed some new light on the basic laws of gravitational interaction and the fundamental nature and structures of spacetime Chapter 1 is devoted to an extensive partly new analysis of the law of inertia The underlying mathematical and geometrical structure of Newtonian spacetime is presented from a four dimensional point of view and some historical difficulties and controversies in particular the concepts of free particles and straight lines are critically analyzed while connections to projective geometry are also explored The relativistic extensions of the law of gravitation and its intriguing consequences are studied in Chapter 2 This is achieved following the works of Weyl Ehlers Pirani and Schild by adopting a point of view of the combined conformal and projective structure of spacetime Specifically Mach's fundamental critique of Newton's concepts of absolute space and absolute time was a decisive motivation for Einstein's development of general relativity and his equivalence principle provided a new perspective on inertia In Chapter 3 the very special mathematical structure of Einstein's field equations is analyzed and some of their remarkable physical predictions are presented By analyzing different types of dragging phenomena Chapter 4 reviews to what extent the equivalence principle is realized in general relativity a question intimately connected to the new force of gravitomagnetism which was theoretically predicted by Einstein and Thirring but which was only recently experimentally confirmed and is thus of current interest     Lasers, Clocks and Drag-Free Control Hansjörg Dittus, Claus Lämmerzahl, Slava G.

Turyshev, 2009-09-02 Over the next decade the gravitational physics community will benefit from dramatic improvements in many technologies critical to testing gravity Highly accurate deep space navigation interplanetary laser communication interferometry and metrology high precision frequency standards precise pointing and attitude control together with drag free technologies will revolutionize the field of experimental gravitational physics The centennial of the general theory of relativity in 2015 will motivate a significant number of experiments designed to test this theory with unprecedented accuracy The purpose of the contributions in this book written by international experts is to explore the possibilities for the next 20 years for conducting gravitational experiments in space that would utilize both entirely new and highly improved existing capabilities     Physics Before and After Einstein Marco Mamone Capria, 2005 It is now a century ago that one of the icons of modern physics published some of the most influential scientific papers of all times With his work on relativity and quantum theory Albert Einstein has altered the field of physics forever It should not come as a surprise that looking back at Einstein's work one needs to rethink the whole scope of physics before and after his time This book aims to provide a perspective on the history of modern physics spanning from the late 19th century up to today It is not an encyclopaedic work but it presents the groundbreaking and sometimes provocative main contributions by Einstein as marking the line between old and new physics and expands on some of the developments and open issues to which they gave rise This presentation is not meant as a mere celebration of Einstein's work but as a critical appraisal which provides accurate historical and conceptual

information The contributing authors all have a reputation for working on themes related to Einstein's work and its consequences Therefore the collection of papers gives a good representation of what happened in the 100 years after Einstein's landmark *Annalen der Physik* articles All people interested in the field of physics history of science and epistemology could benefit from this book An effort has been made to make the book attractive not only to scientists but also to people with a more basic knowledge of mathematics and physics

**One Hundred Years Of General Relativity: From Genesis And Empirical Foundations To Gravitational Waves, Cosmology And Quantum Gravity - Volume 1** Wei-tou Ni, 2017-05-26 The aim of this two volume title is to give a comprehensive review of one hundred years of development of general relativity and its scientific influences This unique title provides a broad introduction and review to the fascinating and profound subject of general relativity its historical development its important theoretical consequences gravitational wave detection and applications to astrophysics and cosmology The series focuses on five aspects of the theory The first three topics are covered in Volume 1 and the remaining two are covered in Volume 2 While this is a two volume title it is designed so that each volume can be a standalone reference volume for the related topic

Foundations of Classical Electrodynamics Friedrich W Hehl, Yuri N. Obukhov, 2012-12-06 In this book we display the fundamental structure underlying classical electrodynamics i.e the phenomenological theory of electric and magnetic effects The book can be used as a textbook for an advanced course in theoretical electrodynamics for physics and mathematics students and perhaps for some highly motivated electrical engineering students We expect from our readers that they know elementary electrodynamics in the conventional 1+3 dimensional form including Maxwell's equations More over they should be familiar with linear algebra and elementary analysis including vector analysis Some knowledge of differential geometry would help Our approach rests on the metric free integral formulation of the conservation laws of electrodynamics in the tradition of F Kottler 1922 E Cartan 1923 and D van Dantzig 1934 and we stress in particular the axiomatic point of view In this manner we are led to an understanding of why the Maxwell equations have their specific form We hope that our book can be seen in the classical tradition of the book by E J Post 1962 on the Formal Structure of Electromagnetism and of the chapter Charge and Magnetic Flux of the encyclopedia article on classical field theories by C Truesdell and R A Toupin 1960 including R A Toupin's Bressanone lectures 1965 for the exact references see the end of the introduction on page 11

**The Galactic Black Hole** H Falcke, F Hehl, 2002-12-16 The supermassive black hole in the center of our Milky Way is the nearest such object and relatively easy to observe and study Not surprisingly therefore it is the best studied supermassive black hole Many astrophysical and even general relativistic effects can be investigated in great detail The Galactic Black Hole Lectures on General Relativity and Astrophysics provides a systematic introduction to the physics astrophysics and mathematics of black holes at a level suitable for graduate students postdocs and researchers in physics astrophysics astronomy and applied mathematics The focus is mainly on the supermassive black hole in the center of our Milky Way but the results can be easily

generalized taking it as an example Leading international experts provide first hand accounts of the observational and theoretical aspects of this black hole Topics range from the properties of the Schwarzschild metric and the collapse of a black hole to quantum gravity and from the structure of the Galaxy to accretion of matter and the emission properties of the Galactic Center black hole

**The Diverse World of PDEs** I. S. Krasil'shchik, A. B. Sossinsky, A. M. Verbovetsky, 2023-08-21 This volume contains the proceedings of the Alexandre Vinogradov Memorial Conference on Diffieties Cohomological Physics and Other Animals held from December 13 17 2021 at the Independent University of Moscow and Moscow State University Moscow Russia The papers are devoted to various interrelations of nonlinear PDEs with geometry and integrable systems The topics discussed are gravitational and electromagnetic fields in General Relativity nonlocal geometry of PDEs Legendre foliated cocycles on contact manifolds presymplectic gauge PDEs and Lagrangian BV formalism jet geometry and high order phase transitions bi Hamiltonian structures of KdV type bundles of Weyl structures Lax representations via twisted extensions of Lie algebras energy functionals and normal forms of knots and differential invariants of inviscid flows The companion volume Contemporary Mathematics Volume 789 is devoted to Algebraic and Cohomological Aspects of PDEs

**Beyond Einstein** David E. Rowe, Tilman Sauer, Scott A. Walter, 2018-06-18 Beyond Einstein Perspectives on Geometry Gravitation and Cosmology explores the rich interplay between mathematical and physical ideas by studying the interactions of major actors and the roles of important research communities over the course of the last century



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