

CP violations in the Universe

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Abstract The origin of the asymmetry between matter and antimatter that is evident in our part of the Universe is one of the open questions in cosmology, because the CPT symmetry between matter and antimatter seems to be absolutely conserved at microscopic level. We repeat here the classical proofs which exclude the viability of a Universe baryon symmetric on the average, or the observed asymmetry as an initial conditions. The current understanding is that the asymmetry should have been dynamically generated before nucleosynthesis, by B, C, and CP violating processes, acting out of thermodynamical equilibrium, as suggested by Sakharov in the 70's. The physical realizations of these conditions would be possible, in principle, also in the framework of the Standard Model of elementary particles, but the present limits on the mass of the higgs particle exclude this possibility. Finally we present the model of baryogenesis through leptogenesis, which is allowed by a minimal extension of the Standard Model, which has the appeal of being testable in future long-baseline neutrino oscillation experiments.

Key words: Cosmology; early universe, elementary particles

1 INTRODUCTION

One of the many providential circumstances about our Universe is its (at least local) “baryon asymmetry”, or, in other words, the fact that in our environment all the massive objects are made of positive protons and negative electrons. The question which immediately follows is why it is so, given the complete equivalence between matter and antimatter established by the CPT theorem, which states that any local quantum field should be symmetric respect to the successive application of a charge conjugation $\hat{C} \equiv q \rightarrow -q$, a parity reflection $\hat{P} \equiv \mathbf{r} \rightarrow -\mathbf{r}$ and a time reversal $\hat{T} \equiv t \rightarrow -t$ as a direct consequence of Lorentz invariance. A testable prediction of the CPT symmetry is the fact that any particle X has an antiparticle $\bar{X}$ with same mass $m_X = m_{\bar{X}}$, same total decay width $\Gamma_X = \Gamma_{\bar{X}}$ and same but opposite charge $Q_X = -Q_{\bar{X}}$. The most accurate test performed (Hagiwara et al. 2002) shows that the mass difference $|m_{K_L^0} - m_{\bar{K}_L^0}| \leq 4.4 \times 10^{-19}$ GeV at 90% C.L., while we have from precision measurements (Yasuguchi et al. 2003) of the mass of antiprotons $|m_p - m_{\bar{p}}| \leq 2 \times 10^{-8}$ GeV at 90% C.L.

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Cp Violations

Hans-Volker Klapdor-Kleingrothaus



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CP Violation Gustavo C. Branco, Luís Lavoura, João Paulo Silva, 1999 CP violation is an intriguing and elusive subject and current knowledge of it remains limited on both the experimental and theoretical levels Researchers lack a fundamental understanding of its origin and this is all the more important because CP violation is related to the generation problem and mass problem two of the basic open questions in particle physics This book provides beginning researchers with a self contained introduction to the subject starting at an elementary level and taking the reader to the forefront of current research

CP Violation L. Wolfenstein, 2012-12-02 The articles collected in this volume are mainly concerned with the phenomenological description of the 1964 discovery on K decay that CP invariance was violated in nature The variety of models developed to explain this CP violation are described together with reprints of more recent definitive experiments and CP violation in the B system and the electric dipole moment of the neutron is also covered

Statistical Physics, High Energy, Condensed Matter and Mathematical Physics Mo-Lin Ge, C. H. Oh, K. K. Phua, 2008 The Conference on Statistical Physics High Energy Condensed Matter and Mathematical Physics was held in honor of Professor Chen Ning Yang's 85th birthday in Singapore in Oct Nov 2007 The conference paid tribute to the breadth and depth of Professor Yang's achievements in physics and science education since he received his Nobel Prize in Physics fifty years ago This unique and invaluable birthday volume is a collection of the presentations made at the conference by many eminent scientists who had worked closely with him or who have been influenced to some extent by his work It covers a wide range of topics ranging from statistical to high energy to mathematical physics

Analysis of the Electric Dipole Moment in the R-parity Violating Supersymmetric Standard Model Nodoka Yamanaka, 2013-11-09 In this thesis the author discusses the phenomenology of supersymmetric models by means of experimental data set analysis of the electric dipole moment There is an evaluation of the elementary processes contributing to the electric dipole moments within R parity violating supersymmetry which call for higher order perturbative computations A new method based on linear programming is developed and for the first time the non trivial parameter space of R parity violation respecting the constraints from existing experimental data of the electric dipole moment is revealed As well the impressive efficiency of the new method in scanning the parameter space of the R parity violating sector is effectively demonstrated This new method makes it possible to extract from the experimental data a more reliable constraint on the R parity violation

Modern Introduction To Particle Physics, A (2nd Edition) Fayyazuddin, Riazuddin, 2000-09-29 The progress made in particle physics during the last two decades has led to the formulation of the so called Standard Model of elementary particles and its quantitative experimental test This book presents that progress and also includes chapters which provide background on modern particle physics Particle physics forms an essential part of the physics curriculum This is a comprehensive book incorporating all the topics for a unified treatment of particle physics It provides good reference material for researchers in both theoretical and experimental

particle physics It is designed as a semester course for senior undergraduates and for graduate students Formal quantum field theory is not used A knowledge of nonrelativistic quantum mechanics is required for some parts of the book but for the remaining parts familiarity with the Dirac equation and Feynman rules is essential However some of these topics are included in an appendix In this second edition many chapters e g on electroweak unification have been revised to bring them up to date In particular the chapters on neutrino physics particle mixing and CP violation and weak decays of heavy flavors have been rewritten incorporating new material and new data The heavy quark effective theory has been included

Proceedings Of The 28th International Conference On High Energy Physics (In 2 Volumes) Zygmunt Ajduk, Andrzej Kajetan Wroblewski, 1997-04-11 The 28th conference from the Rochester series was the major high energy physics conference in 1996 Volume one contains short reports on new theoretical and experimental results Volume two consists of the review talks presented in the plenary sessions **Nuclear Science Abstracts** , 1969 *Origin of Symmetries* C. D. Froggatt, H. B. Nielsen, 1991 The development in our understanding of symmetry principles is reviewed Many symmetries such as charge conjugation parity and strangeness are no longer considered as fundamental but as natural consequences of a gauge field theory of strong and electromagnetic interactions Other symmetries arise naturally from physical models in some limiting situation such as for low energy or low mass Random dynamics and attempts to explain all symmetries even Lorentz invariance and gauge invariance without appealing to any fundamental invariance of the laws of nature are discussed A selection of original papers is reprinted *CP Violation* I. I. Bigi, A. I. Sanda, 2000 This account presents background information and theoretical tools necessary for understanding CP violation Theoretical Methods, Algorithms, and Applications of Quantum Systems in Chemistry, Physics, and Biology Sourav Pal, Vipin Srivastava, Vidya Avasare, Jean Maruani, 2025-08-21 This volume contains peer reviewed contributions based on talks presented at the 26th International Workshop on Quantum Systems in Chemistry Physics and Biology held in Jaipur India in October 2023 It provides an in depth discussion of methodological approaches that are relevant across various length scales elucidating their applications in diverse chemical and biological systems such as catalysis and materials Authored by experts in their respective fields each chapter showcases recent developments and offers insights into the latest research trends This book is aimed at advanced graduate students academics and researchers both in university and corporation laboratories interested in state of the art and novel trends in quantum chemistry physics and biology and their applications *Dynamics of the Standard Model* John F. Donoghue, Eugene Golowich, Barry R. Holstein, 2023-02-16 This 2014 edition now OA provides a detailed and practical account of the Standard Model of particle physics *Beyond the Desert 2003* Hans-Volker Klapdor-Kleingrothaus, 2012-12-06 This book contains the Proceedings of the Fourth International Conference on Particle Physics Beyond the Standard Model BEYOND THE DESERT 2003 Emphasis at BEYOND03 was put on supergravity which had its twentieth birthday that year on neutrino physics and dark matter search and on gravitation and cosmology and some

other very important fields The book presents a timely and valuable overview of the status and future potential and trends in theoretical and experimental particle physics in the complementary sectors of accelerator non accelerator and space physics

Passion For Physics, A: Essays In Honor Of Geoffrey Chew, Including An Interview With Chew Carleton Detar,1985

Gauge Theory of Elementary Particle Physics Ta-Pei Cheng,Ling-Fong Li,1994-08-02 This is a practical introduction to the principal ideas in gauge theory and their applications to elementary particle physics It explains technique and methodology with simple exposition backed up by many illustrative examples Derivations some of well known results are presented in sufficient detail to make the text accessible to readers entering the field for the first time The book focuses on the strong interaction theory of quantum chromodynamics and the electroweak interaction theory of Glashow Weinberg and Salam as well as the grand unification theory exemplified by the simplest SU 5 model Not intended as an exhaustive survey the book nevertheless provides the general background necessary for a serious student who wishes to specialize in the field of elementary particle theory Physicists with an interest in general aspects of gauge theory will also find the book highly useful

Particles in the Dark Universe Yann Mambrini,2024-10-21 This second edition of Particles in the Dark Universe has been substantially enhanced with several new chapters that delve into crucial aspects of particle physics in the Universe These additions encompass the role of primordial black holes in the early universe tracing their formation to decay unification theories a comprehensive historical overview of cosmological models an extensive examination of the physics of the graviton and an educational exploration of gravitational phenomena such as Unruh type or Hawking radiation Additionally this edition incorporates 30 new exercises and provides a comprehensive presentation of inflationary models along with a pedagogical insight into the mechanism of baryogenesis Structured in a logical sequence this book offers a thorough and instructional exploration of particle physics within the early universe It initiates by elucidating the thermal history of the universe delving into pivotal concepts like Big Bang nucleosynthesis the cosmic microwave background CMB and inflation Subsequently it meticulously addresses both direct and indirect detection methods of dark matter followed by an in depth analysis of neutrino physics The book further scrutinizes potential candidates for dark matter and their interactions Designed for theoretical physicists engaged in particle physics within the universe dark matter detection astrophysical constraints and those interested in models of inflation or reheating this book also caters to astrophysicists involved in quantum field theory computations It encompasses all essential elements required for computing various physical processes providing mathematical tables necessary thermodynamic functions for the early universe and Feynman rules Consequently this book serves as an intersecting point between astrophysics particle physics and cosmology

Particle Physics Phenomenology - Proceedings Of The Iv International Workshop Wei Shu Hou,Hsiang-nan Li,Guey-lin Lin,Hai Yang Cheng,1999-09-29 This proceedings volume covers many aspects of the latest developments in B physics exclusive and inclusive charmless B decays CP violation within and beyond the Standard Model perturbative QCD and its application to B

physics spin physics and supersymmetry phenomenology **Energy Research Abstracts** ,1991 Standard Model And Beyond, The - Proceedings Of The Ninth Symposium On Theoretical Physics Jihn E Kim,1991-06-13 The most recent LEP data is included in the lectures The subjects include Higgs physics KM angles weak CP violation neutron electric dipole moment SUSY phenomenology radiative corrections and e e experiments *Lectures on Particle Physics, Astrophysics and Cosmology* Carlos Merino,2014-12-22 This volume gathers the content of the courses held at the Third IDPASC School which took place in San Marti o Pinarío Hospederia and Seminario Maior in the city of Santiago de Compostela Galiza Spain from January 21st to February 2nd 2013 This school is the annual joint program of the International Doctorate Network in Particle Physics Astrophysics and Cosmology IDPASC The purpose of the school series is to present doctoral students from different universities and laboratories in Europe and beyond with a broad range of the latest results and current state of the art in the fields of Particle Physics Astrophysics and Cosmology and to further introduce them to both the questions now posed by the potentials of physics and to challenges connected with current and future experiments in particular with the newly available energy ranges Following these guidelines the content of this third edition of the IDPASC School was jointly planned by the Academic Council and by the network s International Committee whose members ensure every year its timely formulation keeping up with the constant evolution of these fields The program covers a balanced range of the latest developments in these fields worldwide with courses offered by internationally acknowledged physicists on the Basic Features of Hadronic Processes Quantum Chromodynamics Physics and Technology of ALICE LHCb Physics Parity Violation the Higgs System in and beyond the Standard Model Higgs Searches at the LHC Theory and Experiments with Cosmic Rays Numerical Methods and Data Analysis in Particle Physics Theoretical Cosmology and AdS CFT Correspondence Most of these courses were complemented by practical and discussion sessions **High Energy Physics 99 Proceedings of the International Europhysics Conference on High Energy Physics, Tampere, Finland, 15-21 July 1999** K Huitu,H Kurki-Suonio,J Maalampi,2000-01-01 High Energy Physics 99 contains the 18 invited plenary presentations and 250 contributions to parallel sessions presented at the International Europhysics Conference on High Energy Physics The book provides a comprehensive survey of the latest developments in high energy physics Topics discussed include hard high energy structure functions soft interactions heavy flavor the standard model hadron spectroscopy neutrino masses particle astrophysics field theory and detector development

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