

TASI Lectures on the Particle Physics and Astrophysics of Dark Matter

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These lecture notes on the particle physics and astrophysics of dark matter (DM) were delivered at TASI 2022 “Ten Years After the Higgs Discovery: Particle Physics Now and Future.” The focus of these lecture notes, aimed at the level of advanced graduate students and beginning postdocs, is on indirect (*i.e.*, astrophysical and cosmological) probes of particle DM models. While DM models and indirect detection are broadly discussed, the examples of weakly interacting massive particles (WIMPs) and axions are worked out in detail. The topics covered include: the role of DM in the cosmology and astrophysics of structure formation, including DM density profiles in galaxies, general constraints on particle DM models, the theory of minimal DM, with the higgsino as a relevant and illustrative example, indirect detection with gamma-rays, including with the upcoming Cherenkov Telescope Array, axions as a solution to the strong- CP problem and a DM candidate, including discussions of possible ultraviolet completions and of axion string cosmology, and astrophysical probes of axions such as with isocurvature perturbations, N_{eff} , black hole superradiance, radio telescopes, spectral modulations, stellar polarization, and stellar cooling, amongst other topics. Example Jupyter notebooks are provided that walk the reader through relevant analyses, including an example statistical analysis of a DM annihilation search towards the Segue I dwarf galaxy with gamma-ray data from the *Fermi* Large Area Telescope that is relevant for DM explanations of the *Fermi* Galactic Center Excess. We also provide an introduction to frequentist statistics for particle and astro-particle physics. These lecture notes are meant to be pedagogical, with the focus on explaining the underlying physical principles and analysis techniques that are set to play crucial roles in the search for particle DM in the coming decade.

*TASI 2022 – “Ten Years After the Higgs Discovery: Particle Physics Now and Future,”
June 6 - July 1 2022
Boulder, CO USA*

Tasi Lectures In Elementary Particle Phy

**Joseph Polchinski, Pedro Vieira, Oliver
Dewolfe**



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TASI Lectures in Elementary Particle Physics, 1984 [TASI Lectures in Elementary Particle Physics 1984](#) David N. Williams, 1984 **TASI Lectures in Elementary Particle Physics 1984** D. N. Williams, 1984 **TASI Lectures in Elementary Particle Physics**, 1984 [Anticipating the Next Discoveries in Particle Physics](#) Rouven Essig, Ian Low, 2018-08-18 [New Frontiers In Fields And Strings \(Tasi 2015\) - Proceedings Of The 2015 Theoretical Advanced Study Institute In Elementary Particle Physics](#) Joseph Polchinski, Pedro Vieira, Oliver Dewolfe, 2016-11-28 This volume is a compilation of lectures delivered at the TASI 2015 summer school New Frontiers in Fields and Strings held at the University of Colorado Boulder in June 2015 The school focused on topics in theoretical physics of interest to contemporary researchers in quantum field theory and string theory The lectures are accessible to graduate students in the initial stages of their research careers **TASI 2015** Joseph Gerard Polchinski, Pedro Vieira, Oliver DeWolfe, 2016-11-29 This volume is a compilation of lectures delivered at the TASI 2015 summer school New Frontiers in Fields and Strings held at the University of Colorado Boulder in June 2015 The school focused on topics in theoretical physics of interest to contemporary researchers in quantum field theory and string theory The lectures are accessible to graduate students in the initial stages of their research careers *Frank Wilczek: 50 Years Of Theoretical Physics* Antti Niemi, Alfred Shapere, Kok Khoo Phua, 2022-03-18 Frank Wilczek is one of the foremost theoretical physicists of the past half century He has made several fundamental contributions that shape our understanding of high energy physics cosmology condensed matter physics and statistical physics In all these fields his many discoveries continue to play a key role in shaping the direction of modern theoretical physics Among Wilczek's major achievements is the discovery of asymptotic freedom which predicts and explains the ultraviolet behavior of non abelian gauge theories The axion which he co discovered and named has emerged as the prevalent candidate for explaining the origin of dark matter in the Universe His invention of color flavor locking explains chiral symmetry breaking in high density quantum chromodynamics His introduction of fractional statistics and anyons are pivotal to our understanding of the fractional quantum Hall effect and form the building blocks of topological quantum computing His invention of the time crystal concept has catalyzed extensive investigations of dynamical phases of physical systems Frank Wilczek received the 2004 Nobel Prize in Physics for the discovery of asymptotic freedom He is also the recipient of several Prizes and honorary awards including the MacArthur Fellowship the Lorentz Medal of the Royal Netherlands Academy of Arts and Sciences the Lilienfeld Prize of the American Physical Society the High Energy and Particle Physics Prize of the European Physical Society and the King Faisal International Prize for Science of the King Faisal Foundation He is a member of the National Academy of Sciences American Academy of Arts and Sciences and the American Philosophical Society He is also a foreign member of the Royal Netherlands Academy of Arts and Sciences and of the Royal Academy of Sciences in Sweden He is currently the Herman Feshbach Professor of Physics at MIT Center for Theoretical

Physics He also holds a professorship at Stockholm University is a Distinguished Professor at Arizona State University and is the founding director of the Tsung Dao Lee Institute and Chief Scientist of the Wilczek Quantum Center at Shanghai Jiao Tong University This volume serves as a tribute to Frank Wilczek's legendary scientific contributions commemorating his 70th birthday and the first 50 years of his career as a theoretical physicist The contributors include several of his PhD students close collaborators and both past and present colleagues

Cosmology and Elementary Particles Daniel R. Altschuler, José F. Nieves, 1989

Perspectives On Supersymmetry Gordon Kane, 1998-07-03 Supersymmetry is at an exciting stage of development It extends the Standard Model of particle physics into a more powerful theory that both explains more and allows more questions to be addressed Most important it opens a window for studying and testing fundamental theories at the Planck scale Experimentally we are finally entering the intensity and energy regions where superpartners are likely to be detected and then studied There has been progress in understanding the remarkable physics implications of supersymmetry including the derivation of the Higgs mechanism the unification of the Standard Model forces cosmological connections such as a candidate for the cold dark matter of the universe and the scalar fields that drive inflation and their potential the relationship to Planck scale theories and more While there are a number of reviews and books where the mathematical structure and uses of supersymmetry can be learned there are few where the particle physics is the main focus This book fills that gap It begins with an excellent pedagogical introduction to the physics and methods and formalism of supersymmetry by S Martin which is accessible to anyone with a basic knowledge of the Standard Model of particle physics Next is an overview of open questions by K Dienes and C Kolda followed by chapters on topics ranging from how to detect superpartners to connections with Planck scale theories by leading experts This invaluable book will allow any interested physicist to understand the coming experimental and theoretical progress in supersymmetry and will also help students and workers to quickly learn new aspects of supersymmetry they want to pursue

The Standard Model Higgs Boson M.B. Einhorn, 2012-12-02 The Standard Model of electroweak and strong interactions contains a scalar field which permeates all of space and matter and whose properties provide the explanation of the origin of the masses Commonly referred to as the Higgs field it assumes in the physical vacuum a non vanishing classical expectation value to which the masses of not only the vector bosons but all the other known fundamental particles quarks and leptons are proportional This volume presents a concise summary of the phenomenological properties of the Higgs boson

Physics Of The Large And The Small: Tasi 2009 - Proceedings Of The Theoretical Advanced Study Institute In Elementary Particle Physics Csaba Csaki, Scott Dodelson, 2011-03-04 This volume presents a set of pedagogical lectures that introduce particle physics beyond the standard model and particle cosmology to advanced graduate students

Handbook of Quantum Gravity Cosimo Bambi, Leonardo Modesto, Ilya Shapiro, 2024-12-03 The search for a theory of quantum gravity is one of the most important and fascinating problems in modern theoretical physics While we do not have yet a complete theory of quantum gravity

significant advancements have been done in the past decades In this handbook every section is dedicated to a specific approach towards a theory of quantum gravity and is edited by the leading experts in the field This book represents both a valuable resource for graduate students and an important reference for researchers in quantum gravity *The Oxford Handbook of Philosophy of Physics* Robert W. Batterman, 2013-01-04 This Oxford Handbook provides an overview of many of the topics that currently engage philosophers of physics It surveys new issues and the problems that have become a focus of attention in recent years It also provides up to date discussions of the still very important problems that dominated the field in the past In the late 20th Century the philosophy of physics was largely focused on orthodox Quantum Mechanics and Relativity Theory The measurement problem the question of the possibility of hidden variables and the nature of quantum locality dominated the literature on the quantum mechanics whereas questions about relationalism vs substantivalism and issues about underdetermination of theories dominated the literature on spacetime These issues still receive considerable attention from philosophers but many have shifted their attentions to other questions related to quantum mechanics and to spacetime theories Quantum field theory has become a major focus particularly from the point of view of algebraic foundations Concurrent with these trends there has been a focus on understanding gauge invariance and symmetries The philosophy of physics has evolved even further in recent years with attention being paid to theories that for the most part were largely ignored in the past For example the relationship between thermodynamics and statistical mechanics once thought to be a paradigm instance of unproblematic theory reduction is now a hotly debated topic The implicit and sometimes explicit reductionist methodology of both philosophers and physicists has been severely criticized and attention has now turned to the explanatory and descriptive roles of non fundamental phenomenological theories This shift of attention includes old theories such as classical mechanics once deemed to be of little philosophical interest Furthermore some philosophers have become more interested in less fundamental contemporary physics such as condensed matter theory Questions abound with implications for the nature of models idealizations and explanation in physics This Handbook showcases all these aspects of this complex and dynamic discipline *High Energy Physics Index*, 1989 *Weigh Them All!* Sunny Vagnozzi, 2020-08-13 The three neutrinos are ghostly elementary particles that exist all across the Universe Though every second billions of them fly through us they are extremely hard to detect We used to think they had no mass but recently discovered that in fact they have a tiny mass The quest for the neutrino mass scale and mass ordering specifying how the three masses are distributed is an extremely exciting one and will open the door towards new physics operating at energy scales we can only ever dream of reaching on Earth This thesis explores the use of measurements of the Cosmic Microwave Background the oldest light reaching us a snapshot of the infant Universe and maps of millions of galaxies to go after the neutrino mass scale and mass ordering Neutrinos might teach us something about the mysterious dark energy powering the accelerated expansion of the Universe or about cosmic inflation which seeded the initial conditions for the

Universe Though extremely baffling neutrinos are also an exceptionally exciting area of research and cosmological observations promise to reveal a great deal about these elusive particles in the coming years Dark Secrets Of The Terascale, The (Tasi 2011) - Proceedings Of The 2011 Theoretical Advanced Study Institute In Elementary Particle Physics Konstantin Matchev, Timothy M P Tait, 2012-12-31 This volume is a compilation of the lectures at TASI 2011 held in Boulder Colorado June 2011 They cover topics in theoretical particle physics including the Standard Model and beyond collider physics dark matter and cosmology at a level intended to be accessible to students at the initial stages of their research careers **Particle Physics and Cosmology** P. D. B. Collins, Alan D. Martin, E. J. Squires, 1989-06-06 This readable introduction to particle physics and cosmology discusses the interaction of these two fundamental branches of physics and considers recent advances beyond the standard models Eight chapters comprise a brief introduction to the gauge theories of the strong and the electroweak interactions the so called grand unified theories and general relativity Ten more chapters address recent concepts such as composite fermions and bosons supersymmetry quantum gravity supergravity and strings theories and relate them to modern cosmology and experimental astronomy *Physics Briefs* , 1993 **Directory of Published Proceedings** , 1999

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