

# Preface

Effective Theories have been with us since the dawn of science, but it has only been in recent decades that we have found it important enough to give it a clear and voiced name. This new found desire is due in part to our understanding that no finitely written theory is complete. There was a proselytizing impulse among all those who first grasped the vision of Effective Theories. I recall as a Ph.D. student that many fellow students coming out of Boston would repeatedly pepper their conference talks with the words “Effective Theory”, and others sometime joked that they were curiously keen on celebrating their ignorance and lamented how sad it was that they had such weak ambition. It was at the time that many particle physicists were proudly espousing their faith in the “Theory of Everything” being around the corner. The extremes of the two camps were in stark contrast.

Today, the culture and language of Effective Theories have permeated all of physics. It is not controversial and not lamentable. The concepts are deeply ingrained in many other areas of theoretical physics. In the subsequent chapters, several different physics subareas are touched upon but the discussions all revolve around Effective Theories. An abstract definition of the term is given in the first chapter, and fleshed out through examples in the following chapters. It is hoped that by the end the reader will have a good feel for how the concepts of Effective Theories affect the thinking of practicing scientists, and can see the power that explicitly agreeing to the Effective Theory mindset can have in developing richer theories of nature and achieving a deeper understanding.

## Overview of Subjects Covered

In the following chapters, I wish to emphasize various aspects of Effective Theories across various subdisciplines of physics. [Chapter 2](#) discusses the harmonic oscillator from an Effective Theory point of view. The harmonic oscillator is one of the most important models of physics, and shows up in many guises across all subdisciplines. For this reason I have chosen to start there. The chapter is

somewhat allegorical as I go through the story of coming upon a harmonic oscillator system and trying to understand what theory may describe it. The concepts of Effective Theories, and the traps that people may fall into if they do not accept that theories are never complete, are illustrated at each step of the discovery process.

In [Chap. 3](#), I emphasize how blinded we can be to progress if we do not understand that all theories are Effective Theories. I use the example of Newton's law of gravity, and argue that if scientists had the more modern perspective of Effective Theories, they would have not only been quite sure that an anomalous perihelion precession of Mercury would one day be discovered, but they would also have been able to predict roughly what size it would be. As it was the only anomalous precession admitted to the canon after very painstaking experiment and the exhaustion of all other explanations based on mundane effects were analyzed. Reluctantly, the anomaly was accepted and Einstein's theory of gravity ultimately legitimized it.

In no other area of science has Effective Theories played such a prominent role as in elementary particle physics. In [Chaps. 4](#) and [5](#) I focus on this subfield of science. In [Chap. 4](#), I give a brief introduction to the history of Effective Theories in particle physics before coming to the main theme of Effective Theories and the Higgs boson. The Higgs boson is the elementary scalar particle that is said to give mass to all other known elementary particles. It achieves this by spontaneous symmetry breaking, a concept that will be discussed in some detail. However, the compatibility of Effective Theory ideas and the Higgs boson spontaneous symmetry breaking scale is under dispute. The main purpose of [Chap. 4](#) is to enable the reader to understand what this dispute is and to give various ideas that resolve the dispute. Unlike other chapters, this one contains advanced material that one normally does not encounter until graduate studies. The material is there partly to emphasize to the reader that there is no way to speak intelligibly about the subject without that advanced material. Those who already know the background core material may wish to skip directly to [Sects. 4.4](#) and [4.5](#) where the focused discussion on the role of Effective Theories is presented.

Finally, in [Chap. 5](#), I show that the concepts of Effective Theory can play an important role in our theory choice activities. The goal of this chapter is to show the culture of theory choice among practicing particle physicists, which is most often not talked about openly among the physicists, and then to describe how the ideas of Effective Theories can change perceptions of what the "Best Theories" are.

Effective Theories in Physics

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