Preface

There is a hidden sun in a particle
Suddenly the particle opens up its mouth

The earth and the heavens are cut into pieces
In presence of the sun escaping its trap

Rumi
1207–1273

One of the most popular topics in Multiversal Journey's lecture series has been the concept of extra dimensions in space and time. The topic has been covered in many of our conferences within the last few years: four times by the authors of this book.

The word dimension comes from the 14th century Latin *dimetiri* meaning to measure out. Historically, the notion of a dimension has long been used in geometry for centuries. The dimension of an object is specified by its coordinates (degrees of freedom: longitude, latitude, and height). In algebra, the notion of a dimension takes an abstract form such as dimensions of a vector space which are not the same dimensions we experience everyday in life.

In physics, the idea of extra spatial dimensions originates from Nordstöm's 5-dimensional vector theory in 1914, followed by Kaluza–Klein theory in 1921, in an effort to unify general relativity and electromagnetism in a 5-dimensional space–time (4 dimensions for space and 1 for time). The Kaluza–Klein theory didn't generate enough interest with physicist for the next five decades, due to its problems with inconsistencies. With the advent of supergravity theory (the theory that unifies general relativity and supersymmetry theories) in late 1970s and eventually, string theories (1980s), and M-theory (1990s), the dimensions of space–time increased to 11 (10-space and 1-time dimension).

In contrast, to the volume of research that has been conducted in the area of extra spatial dimensions in the last 40 years, not much time has been devoted to multi-dimensional time theories. Earlier attempts in multi-dimensional time theories had problems with violating causality among other issues. Two-time physics, a theory with 4-space and 2-time dimensions, is well covered in this book.

There are two main features in this book that differentiates it from other books written about extra dimensions:

The first feature is the coverage of extra dimensions in time (two-time physics), which has not been covered in earlier books about extra dimensions. All other books mainly cover extra spatial dimensions.

The second feature deals with the level of presentation. The material is presented in a non-technical language followed by additional sections (in the form of appendices or footnotes) that explain the basic equations and principles. This feature is very attractive to readers who want to find out more about the theories involved beyond the basic description for a layperson. The text is designed for scientifically literate non-specialists who want to know the latest discoveries in theoretical physics in a non-technical language. Readers with basic undergraduate background in modern physics and quantum mechanics can easily understand the technical sections.

The two parts of the book can be read independently. One can skip Part I and go directly to Part II which covers extra dimensions in space.

Part I starts with an overview of the standard model of particles and forces, notions of Einstein's special and general relativity, and the overall view of the universe from the Big Bang to the present epoch (Chapters 1, 2 and 3).

Chapter 4 covers basics of symmetry and perspective including local, global, and gauge symmetries.

Beyond the first four chapters, Part I covers two-time physics (Chapters 5, 6, 7, 8, 9, and 10). Two-time physics is the heart of Part I of this book and is best described by its author, Prof. Bars:

> Humans normally perceive physical reality in 3 space and 1 time dimensions and this is encoded in equations of physics in 3+1 dimensions (1T-physics). However, as discussed in this book, 1T-physics systematically misses to predict certain additional real phenomena in 3+1 dimensions in the form of hidden symmetries and hidden relations between apparently different dynamical systems.
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> 2T-physics, which is based on a fundamental symmetry that can be realized only by adding an extra space and an extra time dimensions, is a completion of 1Tphysics that captures the missing information as effects due to the extra dimensions.
>
> According to 2T-physics in 4+2 dimensions, using 1T-physics in 3+1 dimensions is like analyzing only "shadows" on walls by observers stuck on "walls=3+1", while using 2T-physics is like analyzing directly the "substance" in the room by observers in the "room=4+2". The more powerful perspective of being in the "room" makes predictions, beyond those of 1T-physics, that can be tested and verified directly in our own 3+1 dimensional spacetime.
>
> With proper interpretation, some observations in our own spacetime can be used to peek into and explore the extra 1+1 dimensions which are neither small nor hidden.
>
> 2T-physics has worked correctly at all scales of physics, both macroscopic and microscopic, for which there is experimental data so far. In addition to revealing hidden information even in familiar "everyday" physics, it also makes testable predictions in lesser known physics regimes that could be analyzed at the energy scales of the Large Hadron Collider at CERN or in cosmological observations.

The technical sections in Part I are provided in the form of footnotes.

Part II of the book is focused on extra dimensions of space. As was mentioned earlier, one can skip Part I and go directly to Part II. It covers the following topics:

- The Popular View of Extra Dimensions
- Einstein and the Fourth Dimension
- Traditional Extra Dimensions
- Einstein's Gravity
- The Theory Formerly Known as String
- Warped Extra Dimensions
- How Do We Look for Extra Dimensions?

The technical section for Part II is covered at the end under, extra material: the equations behind the words.

I am indebted to Professor Lawrence M. Krauss for writing the foreword to the book. I would like to extend my thanks to the other two members of the advisory council for the book: Professor Mark Trodden and Professor David Finkelstein.

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