

Preface

The Discarded Image was the last book that C. S. Lewis, perhaps better known for his *Narnia* series of stories, wrote. In this final tome, published in 1964, Lewis reflected upon many decades of lecturing, scholarly research, and philosophical thought.

The “image” that Lewis was concerned with was that of the medieval universe, and specifically its complete, compact, and fully determined form. Indeed, the image of the medieval universe is the very antithesis of the one that we have today. Although our universe is inconceivably large, nowhere near fully surveyed, only partially explained, and full of surprises, it does have one parallel with the medieval image: all is connected, and as every medieval astronomer knew, within the microcosm is a reflection of the macrocosm and *visa versa*.

The Large Hadron Collider (LHC) experiment now under commission at CERN [Conseil Européen pour la Recherche Nucléaire]¹ is just a modern-day continuation of this basic ancient tenet, and even though conceived and constructed to test the best present theories of particle physics, the results from the LHC will provide fundamentally new insights into the origin of the universe and its observed large-scale structure. All is connected.

This book will be concerned with the fleshing out of a new image that binds together the macrocosm (the universe) and the microcosm (the world of elementary particles). Our task in the pages that follow will be to “un-weave” the fabric of the universe, and to thereby tease out the intricate strands that connect the Standard Model of particle physics (and its many present possible extensions) to the observed cosmos around us. For indeed, it is now abundantly clear that once in the deep past, some 14 billion years ago, the vast expanse of the observable universe (with a present diameter of order 93 billion light years) was minutely small – a compact cloud of raw bubbling energy, full of future potential, arguably quixotic, and evolving on a mercurial timescale faster than the blink of a tomcat’s eye. Out of the

¹This was the provisional title for the organization at its founding in 1952. In 1954, however, a name change to *Organisation Européenne pour la Recherche Nucléaire* – European Organization for Nuclear Research – was agreed, but the original acronym, for reasons that are not clear, was kept.

primordial microcosm grew the macrocosm that is the universe of today, with its associated flotsam of galaxies, stars, planets, and life.

Verily, since it seems only right to use exulted tones, science and the work of countless observers and cloistered theoreticians have brought us quite an image to deal with. The modern-day image of the universe is full of incredible and unknown wonders. It is an image that would have thoroughly appalled the medieval scholar, not least because of its vast emptiness but also because its dominant components are entirely unknown to us. The mystery of dark matter (most definitely detected, as we shall see in Chapter 5, yet entirely unseen) and the possible existence of dark energy (discussed in Chapter 6) represent the most profound scientific problems of our age. And although it is not known what physical effects underlie these phenomena (yet), the LHC, by smashing head-on the nuclei of two lead atoms, will transport our understanding back to those moments that prevailed just 10^{-25} s after the Big Bang occurred – back to a time before stable matter even existed. Indeed, The LHC, in addition to its many other incredible properties, is also, in essence, a time machine, and this massive collider will enable researchers to study, for the merest fraction of a second, the primordial fire (the so-called quark–gluon plasma) out of which everything that we can now see and feel initially appeared.

The LHC experiment will not only provide researchers with insights as to why the universe has the characteristic form that it does (being made of something rather than absolutely nothing), it will also look for signs of the much anticipated Higgs boson, one of the key theoretical components of the Standard Model of particle physics, since it is generally believed that it is through interactions with the Higgs field that the various elementary particles acquire their mass; and this is no mere ivory-towered problem – without the Higgs (or some similar such mass-generating process) there would be no matter and no us.

Although the history and origins of the LHC will be described in greater detail in Chapter 2, we should provide at least a few words about its incredible properties before moving into our discussion on the basic properties of matter. The LHC is a machine – perhaps symbiotic complex is a better term for it – that can only be described in superlatives. As the medieval astronomer would have marveled at the great cathedrals of Paris and Rome, so the LHC is the pinnacle of modern experimental physics writ large on the landscape (actually under the landscape, as we shall see). We can do little but wonder at the LHC; its intricate yet paradoxically parsimonious structure, along with its sheer scale, leaves us humbled.

Indeed, the mind reels at the very thought that such machines can even be constructed. The numbers speak for themselves: the main accelerator ring is 26,659 m in circumference; the particle beams are manipulated by 9,593 super-cooled magnets that operate at a temperature of -271.3°C (just 1.9° warmer than the coldest temperature that anything can possibly be in the universe); and the system contains about 7,600 km of electrical cable, using strands of wire that if unraveled and joined end to end would stretch to the Sun and back five times over. When fully operational the LHC experiments will generate about 700 MB of data per second, or some 15 petabytes of data per year – enough digital data, in fact, to produce a 20-km-high stack of CDs every year.

The scale is grand, the structure is colossal, the task is Herculean, but the results from the LHC experiment could confirm and also re-write particle physics as it is presently known. The past, present, and future story of the LHC is and will be a fascinating one to follow, and it is an unfolding epic that could conceivably be destined to change our understanding of both atomic structure and the cosmos. All is connected, and within the macrocosm resides the microcosm (Fig. 1).

Fig. 1 An aerial view of the CERN complex. Set amidst the verdant fields of the French-Swiss border, the loop of the LHC collider ring is shown in the image center and foreground, with Lake Geneva and Mont Blanc, the tallest mountain in Europe, in the far distance. (Image courtesy of CERN)



The expectations of the medieval scholar were entirely different from those of today's scientist. Although our forebears would have held out zero expectation of discovering novelty within the universe (and within the properties of matter, for that matter), the modern observer fully expects to find new celestial objects and unexpected behaviors. The LHC is the tool that likely will reveal the new and the novel, and we can certainly expect that not only will our appreciation of the universe be very different a decade from now, but so, too, will our understanding of fundamental particle physics. It is almost certainly going to be a wonder-filled journey.

However, this journey has its associated risks. The LHC has been designed to explore the unknown, and some scientists have suggested that the CERN researchers may be on the verge of opening a veritable Pandora's Box of trouble. Literally, it has been argued that the LHC could release a host of exotic "demon" particles from beyond the borders of known physics – miniature black holes and so-called strangelets that some believe could pour from the LHC and potentially destroy Earth. These are frightening claims, and they must be considered carefully. How safe is the LHC, and how can we be sure that it doesn't pose a serious threat? These are questions that must be answered as we move forward, not only in the following pages of this book but also as we move into the future exploring the microcosm at ever higher energies.

The Large Hadron Collider

Unraveling the Mysteries of the Universe

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2010, XIII, 218 p. 157 illus., 28 illus. in color., Softcover

ISBN: 978-1-4419-5667-5