When Matter Became Mind

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How the Universe Created Consciousness of Itself

By

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Cambridge Scholars Publishing

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This book is dedicated to anyone on planet earth or anywhere else in the cosmos who has ever looked-up in the night to view a dark sky above their head, and even for a moment then had their nervous system shudder, as they reacted to what they were seeing by saying “Wow! …..*What is all of this*?”

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PREFACE

We are merely a way for the universe to know itself – nothing more and nothing less. The physical universe has an intrinsic capacity to produce a memory of its own existence. It has manifested that capability at least once since its birth. The realization of its own existence arrived after a very, very long time following its birth, requiring some 13.8 billion years of cosmic evolution.

The partial goal of this work is to elucidate how the phenomenon of consciousness in human beings came to be. Describing that long, winding road that led to our appearance as self-aware beings on planet earth requires discussion of purely natural processes and events which exist independently of the existence of our consciousness.

In my previous book, *Inside Out: Looking for Ourselves in Time and Space*, I adopted a perspective for examining how we fit into the cosmos emanating from an internal point of view -- the only one we have - that of the thoughts and feelings flowing within us as we live our brief lives.

Now my plan is to essentially transpose that prior title in order to focus on what M.I.T. physicist Max Tegmark categorizes as “External Reality” - the physical and mathematical world whose entire attributes lie outside of ourselves. We owe our entire existence and essence to that universe of space and time filled with matter and energy.

Although nearly all current theories of the origin of the universe incorporate the inflationary model in describing how everything got here, it is not certain that the “multiverse” implications of such an inflationary Big Bang are true. In any case, regardless of whether (as some cosmologists would maintain) we live in a multiverse, my work here will not be pre-supposing anything beyond the *one* universe which we know about, and are part of.

The “hit” TV sitcom *Seinfeld* was described as being a television show about *nothing.* My work here shares part of its theme with that very popular program. I am simultaneously in this book writing about nothing and everything. What will be described in the next 10 Chapters are some details concerning the intersections of mathematical and physical nothingness and “everything-ness”.

When Matter Became Mind also has as part of its theme the notion that the *subject* of the book is the *object* of the book. The individual behavior of human beings is not something so subjective in its essence that it cannot be treated with the same objectiveness with which we treat the outside world of planets, stars, galaxies, and the universe as a whole.

PART I

PHYSICALITY - THE NUCLEUS OF REALITY

1.

How Is It We Are Here?

Existence Precedes Essence

When I was an undergraduate student at the University of Nevada majoring in physics, I took a summer elective course in the Philosophy of Existentialism. It was the only summer course I ever enrolled in during my protracted higher education career.

Philosophy and science share the same subject matter. They each are an academic discipline having the same objective – the attempt to describe the nature of reality. However, beyond that similarity of purpose, they do differ in their respective approaches. Philosophy depends exclusively upon contemplating the universe. The practice of science is foremostly and critically reliant upon experiment.

Existentialism is a highly introspective study. So often when reading the scholarly works of the seminal existential philosophers like Heidegger, Kierkegaard, and Sartre, a person is infused with forlorn, almost melancholy feelings. The topics which those philosophers dwell upon are those involving deeply internal reflections and contemplations of the human being existing in time and space. Death, fear, anxiety, and intentionality, all viewed from the perspective of the suffering human being, dominate their works.

I performed well that summer in the UNLV class. My instructor was a native of Spain, Professor Cyril Pasterk. The lingering phrase of Dr. Pasterk's that has stuck with me to this day is what he would repeat in class frequently: "*Existence precedes essence*".

By the time we get to the conclusion of this book, I hope the reader will recognize that what I am really writing about here is the necessity of realizing that it is the philosophy of physical science which engulfs every other branch of philosophy. Any other area of philosophy is completely subsumed by what I would call *physical existentialism* – an epistemology based upon the fact that the universe, with or without us, does exist. I must start my book now with that single thought!

A Firm Grasp of the Obvious

One day long ago when I was a graduate student at UCLA, we had a dormitory-sponsored picnic. I remember it being held on a Sunday in a grassy field near the residence hall.

The social gathering drew a mix of the dorm's student demographics. Quite naturally many of the science students gravitated toward each other. To break the ice in what so frequently can be difficult "entry-point" conversations in these kinds of events, I uttered something to the handful of us budding scientists who were clustered around one another. I said something to the effect that "we are part of the universe". Those that heard me (they were either studying chemistry or biology - I was the only astrophysics major), quickly answered me, saying: "Dana, you sure do have a firm grasp of the obvious". The ice had broken!

Perhaps I am "Captain Obvious". Yes, it is obvious that we are part of the universe. But that realization is profound also. Humankind is a subset of the largest set of all - the universal set. Our existence is completely tied to the universe itself.

Throughout this book it will be my intent to convey to the reader the many mathematical, physical, and philosophic details relating to our existence in the universe. The universe's existence permits us to know that the universe and everything contained in it *exists.* We arrive at that knowledge from perceptions we form via our senses of the outside world. External reality therefore permeates our brains and becomes our all-encompassing internal reality. Even if we never come to understand the full true details and properties of a given object in the universe, we will nonetheless know *something*, if we are able to establish that the object does exist. Think for a moment about an entity which you don't have to think about in order for that entity to exist. That entity is the universe itself --an *a priori* reality exists whether or not we exist. It reminds me of what the great Relativity theorist John Wheeler said: "In the end, the equations don't fly, but the universe has a life of its own ". So too, that same realization is expressed in Einstein's profound quote about what drove him to pursue his studies of the physical universe. In his *Autobiographical Notes* he said:

> "Out yonder there was this huge world, which exists independently of us human beings and which stands before us like a great, eternal riddle, at least partially accessible to our inspection and thinking. The contemplation of this world beckoned like a liberation …"

Observing the Universe

Of the 5 senses a physiologically non-impaired person possesses, undoubtedly the most valuable one is eyesight – the ability to directly visualize the world around us. I am always saddened whenever I have heard Deep Purple's song entitled "When a Blind Man Cries". It reminds me of the burden a visually-impaired person must live with to not be able to see the stars in the sky.

In the course of several millennia, sky-watchers from all cultures across the globe have gazed at the heavens to try to understand how it is we are here in the cosmos. By peering at the celestial dome above their heads, all of the ancients were able to collectively form *creation* myths and theories in their minds. More about archeoastronomy will be discussed in Chapter 4.

Fast-forward to a quite recent time in human history only about a half-century ago. After all of the refinements made through the ages by the ancients to describe our ultimate origins, it has only been since the 1960's that a rationally reliable scientific explanation of the creation of the universe has emerged – *The Big Bang Theory* [1].

One must realize that it has only been 4 centuries since the advent of our enhanced vision (optically speaking) by which to gain a better understanding of the nature of what exists in the firmament. Not until 1609 had any human being ever observed using a telescope the objects in the sky. The great scientist Galileo was the first to do it [2].

It is quite incredible to think we have only been seriously studying the sky for a little more than 400 years. Now today, the ever-larger, more precise telescopic instruments at our disposal are helping us gain added confidence that we are on the right track in our quest to uncover the truth about who we are, and how we came to be.

The main rationale for arguing strongly in favor of the basic validity of the Big Bang Theory is that it implies there having been a time in the cosmic past when everything we observe today greatly spread-out in an ever-expanding space[3], was once completely compressed into an infinitesimal volume. Our observational evidence for that fact comes from a serendipitous Nobel-Prize winning discovery from the mid-1960s in Radio Astronomy.

Two research scientists at Bell Laboratories, Arno Penzias and Robert Wilson, in calibrating their microwave receiver horn antennae, found a strange, persistent excess of those electromagnetic waves in any direction in the sky to which they were pointing their equipment. After many painstaking efforts to locate the source of the "contamination" of the

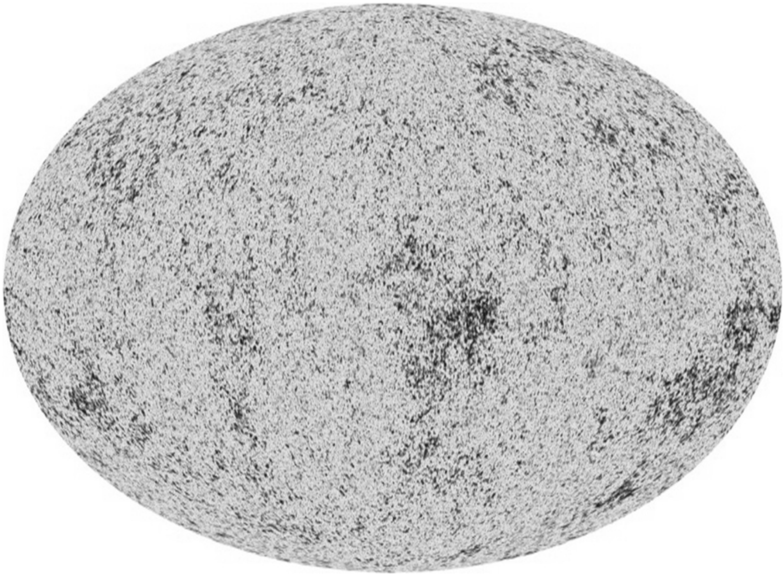

Fig. 1-1. The Cosmic Microwave Background. Planck space telescope image of the oldest light in the universe. Author: NASA's Scientific Visualization Studio – Marit Jentoft-Nilsen, Global Science and Technology, Inc./Mark Malanoski Source: (https://commons.wikimedia.org/wiki/File:Oldest_Light_in_the_Universe_(SVS30133).jpg), „Oldest Light in the Universe (SVS30133)“, marked as public domain, more details on Wikimedia Commons: https://commons.wikimedia.org/wiki/Template:PD-US

data in their experiments, either resulting from isolated celestial sources, or from malfunctioning of their receivers, they found there was a real "Cosmic Microwave Background" signal (abbreviated as *CMB*) propagating from the whole-sky which remained in their data. The inescapable implication of such a monumental discovery in 20th Century astronomy is that what we are seeing now in "microwave light" are the cooled remains of a universe born 14 billion year ago in an ultra-high temperature Big Bang.

The observational confirmation of what the CMB is revealing to us comes from 3 successful spacecraft missions over the past 3 decades. The first, named the Cosmic Background Explorer (COBE), was launched in 1989. Measuring the "all-sky' radiation in wavelengths ranging from a few micrometers to 1 centimeter, the results from the COBE analyses match perfectly the predictions made by Big Bang cosmologists. Those data show excellent agreement between the satellite measurements and the theoretical *blackbody* spectral curve. A blackbody is an ideal object which completely absorbs and re-emits all the thermal energy falling upon it.

The 2 other more advanced spacecraft studying the CMB, the Wilkinson Microwave Anisotropy Probe (WMAP), launched in 2001, and then the Planck spacecraft launched in 2009, each produced successively higher-resolution maps of tiny variations in temperature of the CMB. Figure 1-1 shows the Planck CMB image.

Some Like it Hot!

What was the temperature and density of the universe when it was evidently born at the time of the Big Bang? Can we even compute such numbers? We cannot calculate those numbers exactly at time t=0 seconds. Our equations fail us at the very moment of the Big Bang. But we can estimate how hot the universe must have been immediately after t=0, at a time known as *Planck Time*, t = 10^{-43} seconds.[4] What those somewhat uncertain calculations yield is an almost unimaginably high temperature of perhaps a *hundred million trillion trillion* degrees (10^{32} K). Stephen Hawking in his book *The Universe in a Nutshell* points out that from our observations of the CMB radiation, the density of the universe at that time was probably about 10^{72} tons per cubic inch.

Because we know the universe has been expanding ever since the moment of creation, when we run the cosmological movie backwards, we arrive at that unfathomably large number for the density of matter and energy quoted here. All the material we observe contained in the billions upon billions of galaxies extending outward to some 10 billion light-years of distance was once compressed within a volume perhaps about 10^{-90} cubic meters (a ball having a radius of approximately 10^{-30} meters). Such a nearly infinitesimal, unmeasurably small size would be many orders of magnitude smaller than what we believe the size of a proton to be.

The so-called *primeval atom* of Georges Lemaitre[5] mysteriously caused the Big Bang, and spawned everything there is!

Instant Acceleration

As a refinement to the Big Bang model of the origin of the universe, the theory of *cosmic inflation* was developed in 1979 by Alan Guth of M.I.T. He has had several Russian collaborators with him, contributing greatly to refinements in the theory in the decades since its original development. Foremost among Guth's cohorts are Alexei Starobinsky and Andrei Linde. The story goes something like this:

> Immediately after *t=0* (the time of the *singularity*), lasting for the briefest of moments, the universe expanded unfathomably fast. That *inflationary epoch* lasted from about 10^{-36} seconds after the conjectured Big Bang singularity to approximately between 10^{-33} and 10^{-32} seconds after the singularity.

Inflationary cosmology does appear to provide a plausible explanation of why it is that the universe looks to be *flat* in shape and not curved. It also explains how vastly separated portions of space on cosmological distance scales can have acquired the same temperatures (as evidenced by the WMAP and Planck CMB data) so very early-on after the big bang event. Those 2 problems in Big Bang cosmology are known as the *flatness* problem and *horizon* problem, respectively.

Even though the inflationary model briefly described above is accepted by many physicists, there are still many prominent mathematical scientists who have some strong objections to the seemingly ad hoc features it introduces into cosmology. In fact, one of the principal contributors to the development of the inflationary model, Paul Steinhardt at Princeton University, has in the past couple of decades become one of its most ardent critics. In the thought-provoking book from 2007, *Endless Universe−Beyond the Big Bang*, Steinhardt and co-author Neil Turok (formerly chair of the Mathematical Physics Department at Cambridge University), draw upon the highly theoretical and esoteric elements deriving from *String Theory* (to be discussed in Chapter 3), along with their own interpretations of what the slight temperature inhomogeneity in the Planck CMB map might imply about whether the inflationary cosmology is right or not (or even necessary to invoke in order to explain the very beginning of time and space).

Endless Universe presents an *ekpyrotic* model (the term coined by Steinhardt) which falls under the umbrella of what is known as a cyclic cosmological theory. The ancient Greek word “ekpyrosis”, meaning “conflagration”, connotes a universe born of ‘fire’, that continues endlessly, going round and round in circles of time, and oscillating in space between periods of contraction (occurring before the Big Bang) then to expansion, as a result of the Big Bang phase we see ourselves in now.

Continuing robust work on refining Steinhardt’s original ekpyrotic model is being undertaken by him and one of his current collaborators, Professor Anna Ijjas (now too at Princeton). In the most recent incarnations of their cyclic ekpyrotic model, they are able to demonstrate that it isn’t even necessary to invoke the collision of “branes” (short for *membranes* the essential ingredient in String Theory) in order to describe the physical conditions of the universe as it evolves over the eons in time and space.

There are other versions of cyclic cosmology by which to confront some of the nagging, unresolved precepts stemming from the Guth inflationary paradigm. I would be remiss here right now if I were not to at least mention the one developed by the foremost mathematical physicist of our age – Sir Roger Penrose (full disclosure here, he is quite a scientist hero of mine!). His theory, known as *Cyclic Conformal Cosmology (CCC)*, doesn't involve an eventual contraction of the universe by way of some sort of "Big Crunch". Instead, he posits a different idea based partially upon his puzzlement through the years at the seemingly large level of *entropy* (the measure of disorder) evident in the patchiness seen in the Planck CMB image (Fig. 1-1), when one would expect there should be complete smoothness near the time of the Big Bang. So, he goes on to argue in his CCC model that there might have existed a previous universe that was totally "smooth", which later gave rise to what we believe to be the Big Bang.

Because the cyclic cosmologies (whether it be the ekpyrotic or CCC theory) have as much to say (or predict) about the far future of our universe, let me defer until Chapter 4 further discussion of what the mechanisms and implications are regarding those highly mathematical models. In any event it will be beyond the scope of this book to go into the fine mathematical details contained in them.

The Cosmos Expands and Cools

Whether there ever was the briefest of times when cosmological inflation occurred, the universe that we know about and observe today has grown very, very large in size. Whether we are part of a "*second act*" of a cosmic drama (or in existence because of *many* repeated phases of a cyclic universe), we are here in an expanding universe.

We can divide the history of our universe into 4 distinct eras, each characterized by particular phases in its evolution when energy and matter interacted with one another in a variety of ways. Let me go ahead to discuss, in turn, some salient aspects of those eras.

****

Era 1, we'll call it, is what we have thus far described in this Chapter. It is really still an "Unknown Era"[6]. It represents the exact time of the postulated Big Bang event. All of the 4 forces of Nature would have been completely unified into a single force. Immediately thereafter, electromagnetism, the weak nuclear force, and the strong nuclear force would have acted together as one, in what are called Grand Unified Theories (GUTs). What about gravity − the 4th force? We still do not have a theory which formulates gravity in a quantum mechanical way, to allow its incorporation into the GUTs.

As the universe expanded, it necessarily cooled. The cooling is a consequence of the decreasing energy density in the ever-growing space being produced. The energy at the Big Bang went into the expansion.

Point-sized Particles Appear

Sometime between about 10^{-43} seconds and 10^{-12} after t=0, the 3 forces of the GUT began to separate from one another. The universe throughout this time period would have been a soup of elementary particles known as a quark-gluon plasma. In order to understand somewhat the basic physics going on in Era 2, we need to appreciate the monumental 20th century achievement of modern physics – the formulation of what is called *The Standard Model of Elementary Particles (*SMEP*).* All of what is contained in the SMEP is the result of the most verified physical theory ever developed − *Quantum Mechanics*.

Figure 1-2 shows an organized chart of the presently known types of matter particles known as *fermions* alongside their associated force "messenger" particle manifested in the form of *bosons*. A distinguishing feature of fermions compared with bosons is that the fermions have a value of quantized angular momentum equal to ½, otherwise known as the particle's "spin". The bosons have either a spin=1 (what are called *gauge* bosons) or zero spin (the Higgs boson, a *scalar* boson).

Further categorization of fermions organizes them into (1) quarks and (2) leptons. Categories 1 and 2 also include the anti-particle matched with its corresponding "regular" particle. There are 3 generations of quarks – (*q1*) *Up,Down, (q2) Charm, Strange, (q3) Top, and Bottom.* Likewise there are 3 kinds of leptons – (*l*1) *Electron, Electron neutrino, (l2) Muon, Muon neutrino, (l3) Tau, and Tau neutrino*.

Again, it is beyond the scope of this book to discuss the very complicated interactions and dependencies among this veritable "zoo" of elementary particles. The interested reader is referred to the specialized literature on this subject.

There is however one very important unique, unifying particle discovered barely more than a dozen ago which needs to be brought into our discussion of what was happening during **Era 1**. On July 4, 2012, in the culmination of intense international efforts of scientists and engineers for many years, the long-theorized, much sought-after particle, the *Higgs Boson* was finally verified to exist.

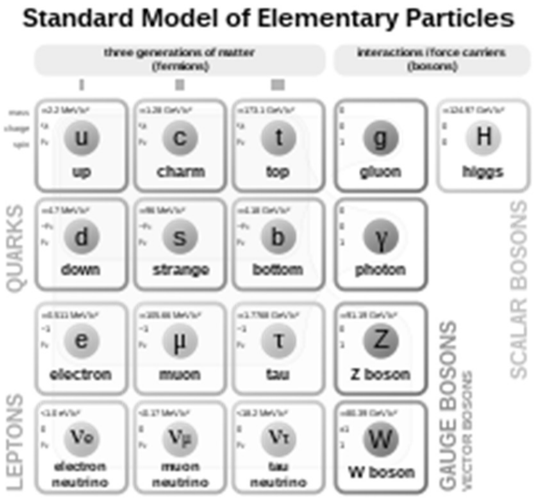

Fig. 1-2. Standard model of elementary particles: the 12 fundamental fermions and 5 fundamental bosons. Author: Cush; Source is own work of Cush using PBS NOVA [1], Fermilab, Office of Science, United States Department of Energy, Particle Data Group (https://commons.wikimedia.org/wiki/File:Standard_Model_of_Elementary_Particles.svg), „Standard Model of Elementary Particles", https://creativecommons.org/licenses/by/3.0/legalcode Attribution: MissMJ – original version

For my money, the experimental confirmation of the existence of the Higgs Boson using the most complicated machine ever constructed, the Large Hadron Collider (LHC), ranks as one of the stupefyingly greatest achievements in the history of physics. You would now be well-served by doing your best in this age of endless "video –streaming" to locate, watch, and absorb the NOVA film from a decade ago entitled *"Big Bang Machine"*. I invariably would show that well-produced film to my college astronomy classes.

The movie chronicles the massive effort spanning decades, to plan, design, and build the LHC. This great particle accelerator is located in Switzerland, at the sprawling headquarters of the European Organization for Nuclear Research (CERN). The LHC resides in a tunnel more than

100 meters below ground. It has a circumference of 27 kilometers. While the gargantuan machine has a total of 9 detectors, each designed to look for different phenomena, 2 of them specifically were used in tandem with each other (but operating independently of each other) in the hunt for the Higgs Boson. One is named *A Toroidal LHC Apparatus* (ATLAS) and the other is the *Compact Muon Solenoid* (CMS).

ATLAS is a real behemoth! It stands 25 meters high, and is 45 meters long. An idea of its immense size is given in figure 1-3. The magnetic field configuration for ATLAS has its magnetic field direction oriented azimuthally to the axis along which the colliding particles travel, whereas CMS has its magnetic field pointing parallel to the particle beam axis. Figure 1-4 shows the 12,500 tonne CMS collider.

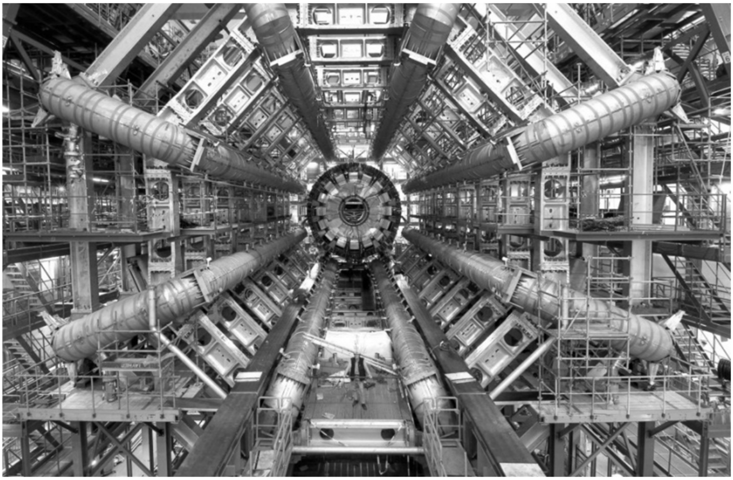

Fig.1-3. ATLAS experiment. Maximilien Brice, CERN (https://commons.wikimedia.org/wiki/File:Installing_the_ATLAS_Calorimeter_-_edit1.jpg), https://creativecommons.org/licenses/by/4.0/legalcode

Only because of the *superconducting magnets* that form the main anatomy of the LHC, could such a premier physics experiment ever get ‘off the ground’. The 2 large magnets used to accelerate protons to nearly the speed of light are the largest of their kind. They contain a stored energy of 3 billion joules. An electrical current of about 20 kilo-amperes flows through the superconductors. Because of the phenomenon of superconductivity discovered over a century ago, wherein all electrical resistance vanishes at cryogenic temperatures for certain ferromagnetic materials, the

LHC can cause streams of elementary particles (usually protons) directed in opposite directions to smash into each other with such force that the underlying components (the quarks) are revealed and studied.

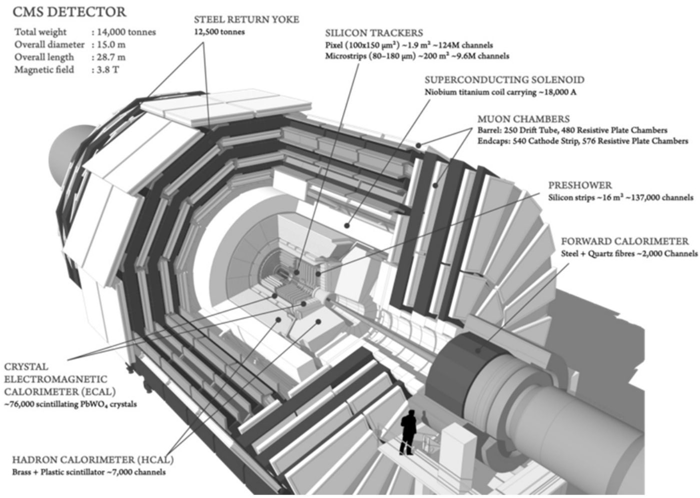

Fig.1-4. Cutaway diagram of the CMS detector after the Phase 1 Pixel upgrade. Tai Sakuma
(https://commons.wikimedia.org/wiki/File:CMS_160312_06.png),
https://creativecommons.org/licenses/by-sa/4.0/legalcode

After an unfortunate hardware mishap governing the magnets in 2008, operation of the LHC was able to resume fully repaired by 2010. In that year, it collided protons with one another at a high energy of *7TeV* (7 trillion electron volts). Repeated, systematic runs were made with ATLAS and CMS through the next couple of years to be able to gain confidence that each instrument was confirming each other's proton-proton collision events, which produced a "bump" in the detected energy at 125 GeV (125 billion electron-volts) – the location in the spectra of particle interactions (detected events) where the postulated Higgs Boson should be found.

Big Bang Machine concludes its 54 minute video drama (which was broadcast live around the world) , with the lead director of the project, Dr. Joseph Candela, onstage in the CERN auditorium, asking the transfixed crowd of technical personnel in attendance to agree that indeed something major was discovered . The audience breaks into giddy applause; and Peter Higgs (now late) is beckoned to walk across the aisle from where he is sitting, with a tear in his eyes, as the applause for him in particular grows even louder. I dare say it is quite a moving moment to climax the movie.

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Now comes **Era 2**. During this era, some 10^{-4} seconds after the big bang, the universe had expanded to about 1 kilometer in extent. By this time, the temperature would have still been greater than a trillion Kelvin. The universe was still hot enough that spontaneous creation and annihilation of particles continued to occur. At about t=0.001 second, a transition of sorts happened when the temperature had fallen enough so that quarks were able to combine into protons and neutrons.[7]

For another several minutes, as more and more protons and neutrons could fuse together to form heavier nuclei, the universe was in a state of *nucleosynthesis*. By the time nucleosynthesis had ceased, the universe still had a temperature $T = 10^9$ K. The universe now was comprised of protons, helium ("He") nuclei, and freely moving electrons. By approximately t = 20 minutes, the universe was no longer hot enough for nuclear fusion, but still too hot for neutral atoms to exist. The photons of light get scattered incessantly by an opaque plasma of electrically charged nuclei. The universe at this stage was in a "quantum fog". Although the universe was dominated by photons then, we don't observe any visible light remnant of that period of early cosmic history.

After about 18,000 years, as the universe continued to cool, helium nuclei began to combine with free electrons to form He^+ ions. Perhaps 30,000 years later, the universe transitions to become "matter-dominated". Until about t=47,000 years, radiation from photons and neutrinos controlled the large-scale dynamics of the universe. After that, the energy density of matter starts to exceed the energy density of radiation. Neutral helium nuclei began forming around t= 10^5 years with neutral hydrogen ("H") formation reaching a peak about 260,000 years after the big-bang.[8]

****

In **Era 3**, atoms begin to form. By the beginning of this era, with the continued cooling of the cosmos, an increasing share of existing particles was in the form of atoms. When that happened, the universe had truly begun planting its first real physical seeds of creation – *the atom.* The enshrined quote of the great, inimitable 20th century physicist Richard Feynman sums up how important the existence of atoms is in our world. As he intones in his famous *Lectures on Physics:*

> "…If, in some cataclysm, all of scientific knowledge were to be destroyed, and only one sentence passed on to the next generations of creatures, what statement would contain the most information in the fewest words? I believe it is the atomic hypothesis (or the atomic fact, or whatever you wish to call it) that all things are made of atoms – little particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling upon being squeezed into one another. In that one sentence, you will see, there is an enormous amount of information about our world, if just a little imagination and thinking are applied."

Throughout this third era, known as the era of *recombination,* neutral atoms of hydrogen could remain stable, so that a single electron could comfortably orbit the hydrogen nucleus (a single proton). The electron now has combined with the proton to create atomic hydrogen. The term "recombination" is a misnomer in the sense that the electrons are combining with atomic nuclei during this era for the first time in the universe's history.

By the end of the recombination era, at approximately t = 380,000 years, with the formation of neutral atoms, the universe became transparent to electromagnetic radiation (i.e., visible light, radio waves, etc.). By that time, the universe would span about 100,000 light-years in radius. One light-year is the distance travelled by photons in one year. It is approximately 10^{16} meters. The photons emitted by the newly formed hydrogen atoms would correspond to a temperature of about 4,000 Kelvins. That temperature would correspond to sort of a pale yellow-orange color.[9]

At this point, some discussion of the nature of electromagnetic radiation (E&M) is in order. Whether we treat the E&M radiation as consisting of *waves* of electromagnetic energy propagating at the speed of light (symbolized as *c*), or as massless *particles,* photons, moving through the universe also at *c*, the universe, as we see it, has revealed its physical properties to us entirely from the light coming to us from near and far[10]. Our eyes and telescopes collect and record that E&M energy.

The roots of *modern physics* (i.e., *quantum mechanics*) date back more than a century. The classical physicists of the late 19th Century wrestled with finding explanations to account for the fact that as a body is continually heated, due to a principle known as *equipartition of energy*, there should gradually be observed, as the object becomes hotter and hotter, a greater and greater amount of very short-wave radiation being emitted in the ultraviolet portion of the E&M spectrum. What is called the "ultraviolet catastrophe" is what then would occur eventually as the object reached higher and higher temperatures such that X-Rays and Gamma-Rays would finally dominate the observed thermal radiation.

But the ultraviolet catastrophe in fact is not what occurs! We must thank the great German scientist, Max Planck (a classical physicist!), for being able to rescue us from being 'fried to a crisp' whenever we look at the heat coming from a burner on a stove, for instance.

It was Planck, at the very start of the 20th Century, who was among the very first developers of Quantum Theory. His whole career was steeped in thermodynamics; he literally wrote the book on thermal radiation! To quantify the degree of this thermal energy at the microscopic level, we define the temperature of an ensemble of particles (atoms or molecules). It is given by the formula: $E = kT$, where E is the average energy per particle, k is the Boltzmann Constant (named for another great thermodynamicist), and T is the temperature of the particle, expressed in Kelvins.

The resultant radiation emitted then from an object having temperature T consists of a spectrum of different wavelengths (λ) of light, each wavelengths being produced with a given intensity according to the energy states (levels) prescribed by the laws of the quantum mechanics (QM).

Here then is Planck's great breakthrough to help us avoid the UV-catastrophe. The radiative energy of the given atom is also given as $E = hv$ in the QM formulation. The quantity "hv" is the energy of a "quantum" of light, proportional to the frequency (ν) of the emitted light. The constant of proportionality is h, *Planck's constant* (a very small number = 6.64×10^{-34} joule-sec). It turns out because of QM, that the quantized energy levels of the excited atom at the greatest frequencies (i.e, UV-wavelengths and shorter!) do not contain an electron (or electrons) to fall back down toward the nucleus to be able to emit as much higher frequency light.

Figure 1-5 shows therefore what actually is observed when the radiation from a perfectly absorbing and emitting object (known as a *blackbody*) is measured. The intensities of the emitted light as a function of the wavelength (or *color*) follows what is called the *Planck Curve.* It is immediately evident upon looking at the curve that as the blackbody is heated to higher and higher temperatures, the emitted intensities rise, and a greater percentage of the emitted light is at increasingly smaller wavelengths, with a peak of the intensity occurring at λ_{peak}. From measurement of λ_{peak} the temperature of the blackbody can be deduced.

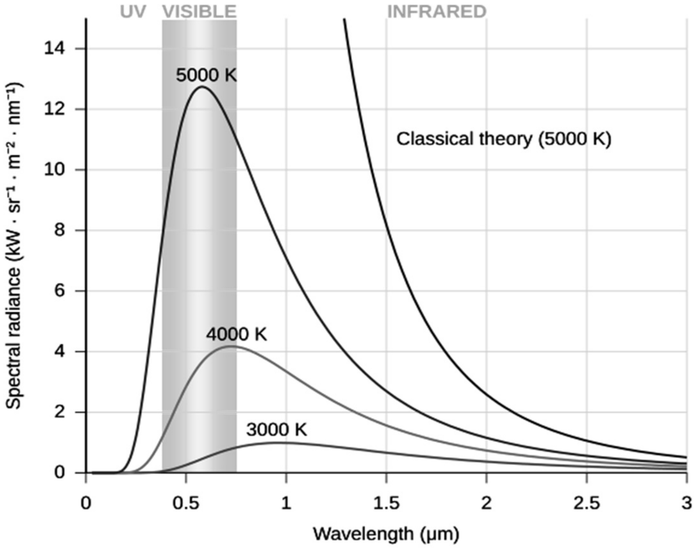

Fig. 1-5. The Planck Curve. Blackbody spectral radiation curves. Darth Kule (https://commons.wikimedia.org/wiki/File:Black_body.svg), „Black body", marked as public domain, more details on Wikimedia Commons: https://commons.wikimedia.org/wiki/Template:PD-self

Stars and Galaxies Appear

The universe needed to age by a factor of about 1,000 *post*-recombination before there was an appreciable ability of atoms to aggregate with each other in large enough amounts in order to form large-scale cosmic clouds of material. So from the end of the recombination epoch until perhaps about 400 million years after the big bang, the photons had been decoupled from matter as the universe continued to cool. Light could travel long distances. The universe was transparent. It wasn't until regions of ever-expanding space could form stars and galaxies by which to produce new light that the cosmos could evolve out of its so-called "Dark Ages".

Within the past few decades, from intensive observations of how stars at differing distances from the centers of their host galaxy revolve around it, the postulation of there being an unseen form of matter acting within space to correctly account for the galactic orbits of those stars is now a near-certain fact. The source of the extra gravitational force necessary to explain those stellar motions is known as *dark matter*. We are not able to directly see dark matter (that's why it is called "dark"). Further-more, we do not know what constitutes it. From all of the indirect evidence of dark matter's existence, it is thought that it comprises about 85 percent of all matter in the universe. The remainder is in the form of ordinary matter.

The presence of dark matter helps explain how material in the earlier universe, through the force of gravity, could have come together in large enough quantities to begin forming some large-scale structure in the cosmos, albeit in a rather amorphous form, resembling long filaments or expansive haloes of material. In figure 1-6, we see a computer simulation of what early large-scale structure in the universe after a few hundred million years post-big bang might have looked like.

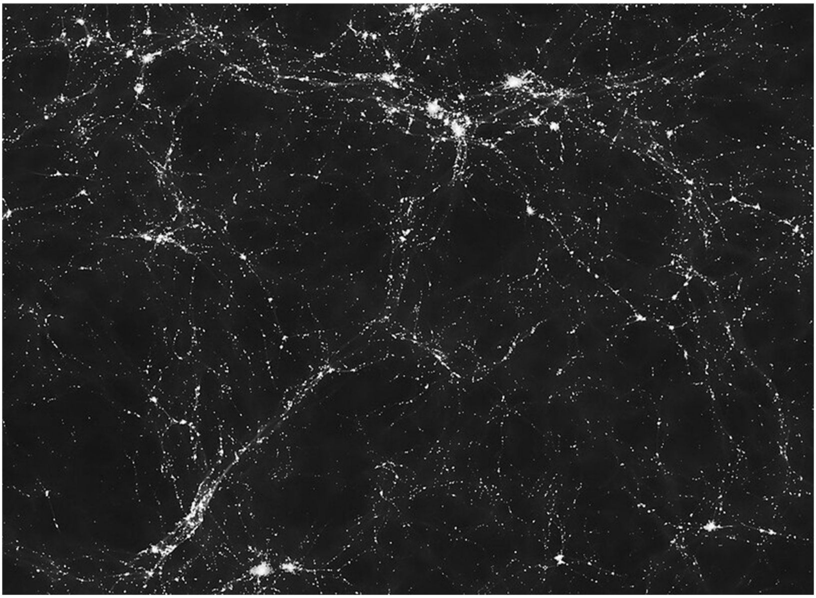

Fig. 1-6. Computer simulation of emerging large-scale filaments of material in the early universe. Andrew Pontzen and Fabio Governato (https://commons.wikimedia.org/wiki/File:Large-scale_structure_of_light_distribution_in_the_universe.jpg), „Large-scale structure of light distribution in the universe", https://creativecommons.org/licenses/by/2.0/legalcode

Ultimately, after another few hundred years after filaments formed, fully recognizable galaxy structure with newly born stars would appear. Then after about a billion years from the beginning, the earliest galaxies with fully delineated spiral structure containing gas and dust, and old evolved stars in their central regions, would emerge.

We move along now in our cosmic chronology journey through time and ever-expanding space, in our arbitrary listing of distinct eras, to describe where we are now, as we have been attempting to answer “How is it we are here?”

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Era 4

Our universe has not stopped expanding since its birth almost 14 billion years ago. During the first era, if *inflation* is the correct model, it expanded almost unimaginably fast within the first trillionth of a second. Then in the second and third eras expansion slowed considerably from what it was during the postulated inflationary period. It will be shown shortly that by the time of Era 4 (our present epoch), the rate of expansion has been increasing.

Faster when Farther

The most important observational discovery in astronomy during the first half of the 20th century was made by the American astronomer Edwin Hubble in 1924. There is a *reason* the Hubble Space Telescope (HST) is named in honor of *him.* What he accomplished using the revered 100 inch Hooker telescope at Mt. Wilson Observatory above Pasadena, California ushered in a whole new era in our understanding of the size and scope of the universe. Until Hubble’s work, it was thought that the entire universe was contained within the spatial bounds of the Milky Way – our home galaxy. A controversy raged at the time concerning the location of what were called “spiral nebulae” – telescopic objects which looked like fuzzy, diffuse patches of light in the sky. What took place on April 26, 1920 at the U.S. National Academy of Sciences in Washington D.C., known as the “Great Debate”, pitted Harvard astronomer Harlow Shapley against Heber Curtis, of the University of Virginia. Shapley believed those spiral nebulae were all within our own galaxy, whereas Curtis took the position they were located much farther away, beyond the Milky Way, and were in fact separate “island universes”.

Edwin Hubble’s landmark observations settled the issue between Shapley and Curtis once and for all. Hubble made systematic observations with the 100 inch of the Andromeda Nebula (as it was known then). He could measure the apparent brightness of a certain type of pulsating star – a Cepheid Variable, whose changes in brightness obeyed a very regular