

"Many worlds, many Universes -- a Consideration of Cosmology from Astrophysics and a Multicultural Perspective."

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“With the success of scientific theories in describing events, most people have come to believe that God allows the universe to evolve according to a set of laws and does not intervene in the universe to break these laws. However, the laws do not tell us what the universe should have looked like when it started – it would still be up to God...”

Steven Hawking, “A Brief History of Time”

“Superstrings and butterflies are examples illustrating two different aspects of the universe and two different notions of beauty. Superstrings come at the beginning and butterflies at the end because they are extreme examples... They mark the extreme limits of the territory over which science claims jurisdiction.. Scientifically speaking, a butterfly is at least as mysterious as a superstring”

Freeman Dyson, “Infinite in all Directions”

“There is a thing confusedly formed,
Born before heaven and earth.
Silent and void
It stands alone and does not change.
Goes round and does not weary.
It is capable of being the mother of the world”

Tao te Ching, D.C. Lau, translation.

Our current picture of astrophysical cosmology is one in which observational constraints place increasingly precise limits on what were formerly poorly determined cosmological constants. In previous decades, the extreme lack of observational certainty gave rein to a wide-ranging debate on the philosophy of cosmology in which very diverse astrophysical cosmologies were entertained, including steady-state cosmologies, cyclical or closed cosmologies, and cosmologies in which matter and anti-matter exist in equal measure.

The improvement of astrophysical observations has the effect of limiting the parameters in which we may debate the meaning and larger philosophical implications of cosmology. To help sharpen the focus of our discussion, I provide

a brief review of some key cosmological parameters are presently known, along with a discussion describing how these parameters affect some of the philosophical questions. Perhaps more importantly, I will also discuss the presently unknown cosmological parameters from astrophysics, and the open questions raised by them in our discussion of the boundaries of science and religion.

The large-scale structure of the universe is clearly one in which matter is insufficient to provide closure to the universe. The Friedman equations for the universe which set the stage for observational cosmology include as parameters H_0 , q_0 , and Ω , which determine the scale factor R of the universe as a function of time.

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TIFF (Uncompressed) decompressor
are needed to see this picture.

Where we have H = the Hubble constant, a = the scale factor of the universe, and K = a curvature constant which has a value between $-1 < K < 1$ depending on the nature of the universe, and ρ and Λ as the density of the universe, and the cosmological constant respectively.

This equation also includes within it densities of the universe, which are more commonly written in terms of Ω , which is defined as the ratio of the density of the universe to the “critical density” in which the matter of the universe is exactly of the right quantity to decelerate the universe to a halt at infinite time:

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By observing galaxy clusters, motions within galaxies, and large census data on galaxies, astrophysics has placed very low limits on Ω_b , the “baryonic” contribution toward the mass density of the universe arising from all the atoms in the universe, and Ω_m , the total density of matter (baryonic and dark) in the universe. Additional constraints arise from observations of the microwave background radiation, in which small-scale variations give rise to anisotropies which have different angular size spectra depending on the parameters H , Ω , and Λ . The last of these parameters is often written as Ω_Λ , the contribution of the density of the universe due to cosmological constant energy density, popularly known as the “Dark Energy.”

The best observational constraints on Ω have recently been summarized by Spergel et al, 2006 and by Lahav and Little, 2005. These papers include data

from measuring supernovae at high redshifts, which provide good constraints on the rate of expansion of the universe, along with data from the cosmic microwave background radiation using the recent Wilkinson Microwave Anisotropy Probe (WMAP) satellite, and data from studying clusters of galaxies. The various techniques are complementary, and combining them allows us to constrain the values of cosmological parameters to great precision, as shown in the figure below.

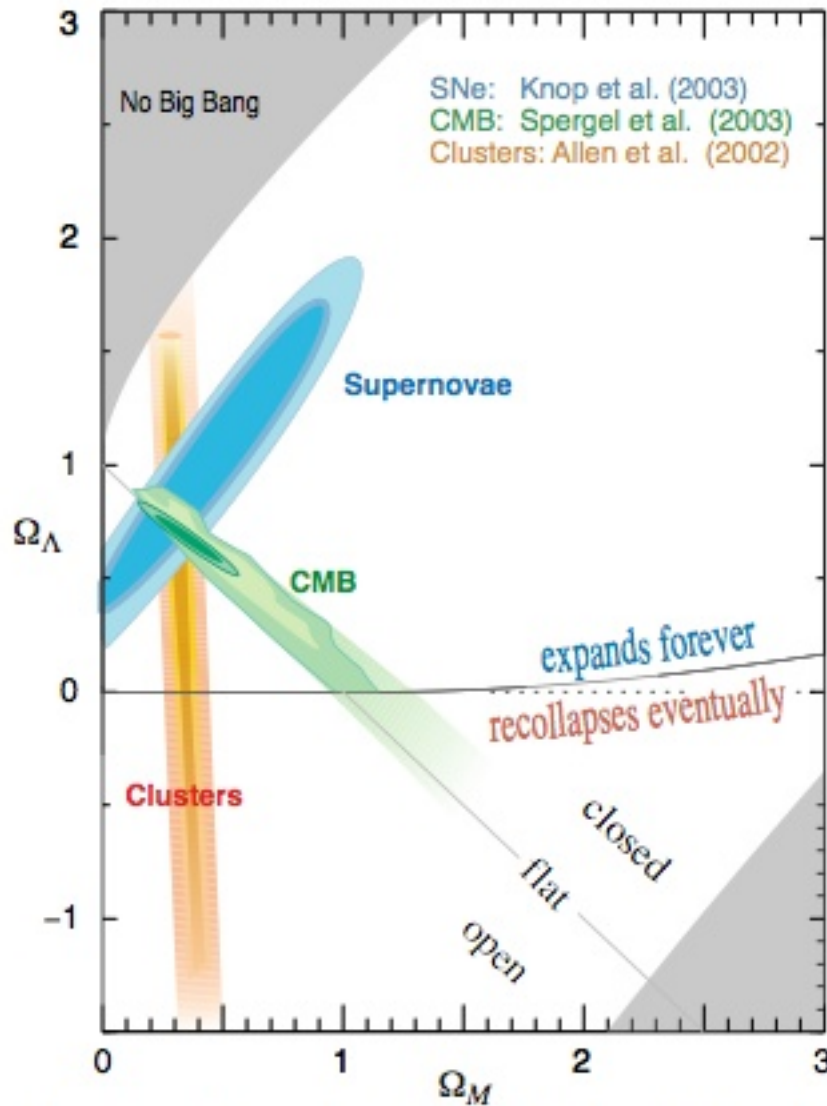


Figure 1 – (from Lahav and Little, 2006). Summary of values of Ω_m , the density of baryonic and dark matter in the universe, and Ω_Λ from combined observations of supernovae, clusters of galaxies, and the Cosmic Microwave Background (CMB) using the Wilkinson Microwave Anisotropy Probe (WMAP).

The results from these recent astrophysics experiments provide very accurate constraints on the fundamental parameters of our universe, enabling a new era

of “precision cosmology”. These developments are so impressive that George Smoot, one of the designers of the COBE satellite described the modern experiments on cosmology as like “looking at God”. One measure of the importance of cosmological background observations is that two different Nobel Prizes in physics have been awarded to those who have measured the background radiation; Penzias and Wilson in 1978, and most recently the 2006 Nobel Prize in Physics was awarded to Smoot and Mather. Some of the results from precision cosmology using the CMB are summarized below, including accurate values of the key parameters H_0 , Ω_b , Ω_Λ and Ω_m .

$$\begin{aligned} H_0 &= 73 \text{ km s}^{-1} \text{ Mpc}^{-1} \pm 3 && \text{(Hubble Constant)} \\ \Omega_b &= 0.0223 \pm 0.0008 && \text{(Baryonic density as fraction of critical density)} \\ \Omega_\Lambda &= 0.72 \pm 0.04 && \text{(Dark Energy density as fraction of critical density)} \\ \Omega_m &= 0.127 \pm 0.009 && \text{(Total matter density, including Dark Matter)} \end{aligned}$$

From the results above, it is clear that the matter which comprises our bodies, our planet, and all the visible material of galaxies observed with all of our telescopes makes a very small component of the universe, at a level of just over 2% of the density of the universe. This ordinary or “baryonic” matter is perhaps accurately described as a “contaminant” on the much large mass of dark matter and dark energy. The philosophical implications are obvious, since now it is clear that the observed matter which has been studied in physics and astronomy is the tip of a much larger “iceberg” of dark matter and dark energy. Galaxies we observe have been likened to the “whitecaps” on top of much larger “waves” of matter and energy which pervade the universe. Paradoxically, along with the new exquisite precision of cosmological parameters comes the the complete mystery of what substance comprises 98% of the mass and energy density of the universe!

Laboratory physics experiments involving particle accelerators, and large detector systems buried deep underground, have been making some progress in constraining the properties of dark matter, which comprises about 10% of the universe. Candidate particles include massive neutrinos, axions, supersymmetric particles (neutralinos, sneutrinos, gravitinos), “scalar particles”, magnetic monopoles, and other exotic particles predicted by new particle physics theories. As reviewed by Bertone, Hooper and Silk, 2004, the dark matter observations are a very active branch of physics and astrophysics, involving dozens of international collaborations funded by billions of research dollars. Laboratory experiments have limited the mass of the neutrino to $m_\nu < 0.2 \text{ eV}$, which limits the neutrino to comprise a fraction $\Omega_\nu < 0.07$. Additional experiments looking for spectral properties of gamma rays, atmospheric Cherenkov radiation from cosmic rays and other signatures of massive dark matter particles have as yet been unsuccessful in identifying viable candidates, but are providing some useful constraints in terms of allowed masses of dark matter particles. While the exact candidate particle has not been identified, it is likely that one of the “Supersymmetric” counterparts of matter could provide a majority of the dark

matter.

Our lack on knowledge about the nature of the Dark Matter is matched only by the nearly complete lack of knowledge of the nature of the observed “Dark Energy” inferred from precise measurements of the radial velocities of galaxies with supernovae. The dark energy is typically associated with vacuum zero point energy, and is often described in relation to the Casimir effect in which vacuum energy density can be shown to exist, or in terms of vacuum energy density which cause virtual particle/anti-particle pairs to be produced within extremely short time intervals.

Regardless of the exact nature of the Dark Energy, it has an important effect for our discussion of philosophy and religion in cosmology, since Dark Energy dictates that the long-term future of our universe. With the Dark Energy, it is easily shown that the Universe obeys an exponential expansion, since the Dark Energy is thought to be a scalar field which increases in proportion while the matter of the universe is diluted through expansion. This means that at large times in the future, the scale of the universe will expand exponentially, thereby diluting the density and decreasing the temperature of the universe toward absolute zero. Philosophically, this presents our universe with a dismal future, and one from which we cannot escape, since the accuracy of modern observations make it very difficult to exclude the near certain runaway expansion predicted by the dark matter and dark energy observed in the universe.

From the results of modern astrophysics and precision cosmology, it appears that we humans inhabit a location in the universe in which our (baryonic) composition appears to be a very minor constituent of the universe, during a time at which the density and temperature of the universe are suitable for life to exist, and where the universe is on the precipice of exponential expansion in which the density of matter and energy will drop suddenly, thereby isolating galaxies in the rapid cooling of the universe.

Another very intriguing result with profound philosophical implications is that it is now believed both from observations of WMAP and HST that the total matter density of the universe Ω including dark matter and dark energy appears to be about 0.85, and not 1.0 as had been expected from inflation theory. This may also be compelling evidence to dispute those who argue that the universe is “fine-tuned”. The lack of exact agreement of $\Omega = 1$ increases the fraction of parameter space in which our universe may exist, and lessens the uniqueness of our universe, making it more likely that our observed mass density appears randomly from the conditions in the early universe.

Another result from astrophysics worth considering is that matter dominates over antimatter only due to chance asymmetry in the early universe, at a level of one part in a billion. The presence of any residual matter at all appears due to this imperfection, and argues that our universe is indeed a matter of random chance.

However, to some this imperfection could in fact be seen as a sign of “design,” according to notions of aesthetics that include intentional asymmetry. In Japanese art, this intentional asymmetry is known as “hacho” and it results in slight imperfections built into the architecture of temples and statuary to improve their beauty. In evaluating the implications of physical cosmology, and the likelihood of “design” in the observed properties of our universe, we have to caution that one is necessarily appealing to non-rational, aesthetic and culturally dependent impulses in validating interpretations.

As we constrain the large-scale behavior of the universe, our knowledge of small-scale effects on physics is attempting to push back the earliest moments in which we can model the evolution of the universe. However due to the breakdown in our existing physical laws at high energies (the so-called “Planck Era”), it is unknown what exact physical laws apply at the first instances of the Big Bang. Despite this, within the Big Bang comes the concept of a “phase transition” in which the Higgs field collapses and produces the initial explosive energy that expanded space and triggered the inflationary epoch. The exact nature of these early particles are still a matter of theoretical speculation.

The Big Bang cosmology presents a nearly complete edifice in which the basic physical parameters of the universe can be described. Yet certain questions do remain – is the universe the result of a random, stochastic process, or instead a unique event? At the present time, we lack sufficient scientific knowledge to answer definitively, but we can state objectively that the universe displays set of properties more consistent with a random or “stochastic” process than the result of “fine tuning”. The randomness of the universe is supported by observations which include the asymmetry of matter and anti-matter, the lack of observational evidence to support $\Omega = 1$, the random fluctuations needed to produce the inflationary epoch, and the fact that our existence as a species relies on a long series of random events, culminating in self-aware life forms constructed of chemically altered and elementally anomalous debris in a small corner of a non-descript galaxy.

On the other hand, the nature of the initial singularity, the amazing possibility that the universe is poised between two infinities – one infinitesimal singularity and our later expansion into the void at exponential rates, suggests that in many ways we occupy a privileged position; and one which begs the question of who and what could have started all of this?

With our knowledge of physics we can point to several additional mysteries of the universe, integral to our universe’s structure of space and time, which have important philosophical and religion implications. These include the nature of quantum reality in which wave functions are delocalized, entangled across great distances in space, and subject to complimentarity with observers. Much has been written about these essential physics paradoxes, including the famous Schroedinger’s Cat experiment, which explains superposition of eigenstates in

quantum mechanics, and the Einstein Podolsky Rosen paradox, which results in some of the fascinating experiments in entanglement of quantum states. The demonstration of Bose-Einstein condensates, resulting in interference, diffraction and other wave-like properties of matter at low temperature further challenges our conception of objective reality.

The physical universe at the microscopic level is one in which the identity of particles, their physical locations, and their energies, and natures are difficult to constrain exactly, and are subject to change or “collapse” by the very action of experimentation. However, even within the limits of measurement, the fact that fundamental constants such as mass, charge, spin, parity and isospin are all conserved and identical among the trillions of particles in a single grain of sand give credence to the idea that physics can reveal some of the most profound underlying realities of our universe.

The quantum realm does however challenge the natural “common-sense” way of thinking of most people, and goes against how our consciousness naturally has evolved. In the same way that creatures on earth have evolved vision to adapt to the particular frequencies of light which emerge from our sun, so perhaps our minds have adapted to the particular natures which matter exhibits in our macroscopic universe. Therefore the concept of identity, of individuality, of consciousness, and of one’s relationship with the Universe and God all arise from a conception of observers who may separately exist, and objectively interact with the components of the physical universe. Many of our religious traditions reflect this “subject/object”, “conscious identity” form of interaction with the universe, in which we attain identity or “soul” as we relate to the universe, and in relation to the God which we acknowledge.

The subject/object construction and the emphasis on individuality is implicit in the familiar passages of Genesis:

“And the Spirit of God moved upon the face of the waters.. And God said let there be light, and there was light...”

“And God blessed them and God said unto them, Be fruitful and multiply, and replenish the earth and subdue it”

Genesis 1:3, 1:28.

The active creator, imparting his individuality to the universe is also seen in the religion of Zoroastrianism, in the form of Ahura Mazda:

“I created the stars, the moon, the sun, and the red burning fire, the dogs, the birds, and the five kinds of animals, but better and greater than all, I created the righteous man who has truly received from me the praise of Asha in the good religion”

Aogemadaecha. 30., as quoted in Champion and Short, 1951.

Likewise in Islam, creation is described as the construction of an objective reality by an active conscious creator:

“Your Lord is God, who in six days created the heavens and the Earth and then mounted the throne: He throweth the veil of night over the day: it pursueth it swiftly: and he created the sun and the moon and the stars, subjected to laws by His behest: Is not all creation and its empire His? Blessed be God the Lord of the Worlds”

Sura VII, Al Araf: 52, as quoted in Leeming and Leeming 1994.

In the quantum context however, we must acknowledge that the observer and observed are inseparable, that space and time are inseparable, and objective reality becomes split between that which is observed, and that which has the potential to be realized; the quantum state which has not yet been measured. As the Schrodinger's Cat physics thought experiment demonstrates, matter will exist as a superposition of eigenstates until the point of measurement, which causes the quantum wave function to collapse into one of the eigenstates appropriate to the experiment. This conception can have root in many religions, and underlies some of the more mystical elements of Christianity, Hinduism, Taoism, Buddhism and other religions.

From Hinduism comes many expressions of the complementarity principle in which observer and observed are inseparable; even the account of the creator includes the creator as inseparable from the created Universe:

“He (God) is the light of all lights and luminous beyond all the darkness of our ignorance. He is knowledge and the object of knowledge. He is seated in the hearts of all”.

Bhagavad Gita 13. 17., as quoted in Champion and Short, 1951.

The Hindu creation can be seen as an inward journey:

“Then was there neither day, nor night, nor light, nor darkness,
Only the existent One breathed calmly, self-contained.
Naught else than him there was – naught else above, beyond....
Then turning inwards, He by self-developed force of inner fervour and intense abstraction, grew.”

From the Rig Veta, as quoted by Champion and Short, 1951.

Ultimately, however, it is my belief that human beings create religion, in the same way that human beings create physics experiments. The fact that certain

religions match our current understanding in certain ways can be seen as evidence of the validity of the religion. However, an alternate interpretation is that religions in many ways are experiments in explaining the ultimate nature of reality, which sometimes fail and sometimes succeed. Many religions are self-contradictory, and contain within them passages which can argue both for and against individual conceptions of reality and consciousness.

As we typically give most credence to the mainstreams of contemporary religion, we also are necessarily sampling a subset of the religions practiced by mankind, and are completely missing many traditions which come from indigenous societies which may not have developed writing, or from earlier cultures which are no longer extant. To some degree the evolution of religious thought would be expected to go in parallel to the development of human consciousness, and in such an evolutionary paradigm, these earlier religious experiments could be seen to have gone extinct for many of the same reasons as biological species become extinct. A religion that no longer matches the conceptual framework of its people can be modified or replaced with one that does, and in some cases these vanished religions mirror earlier states of consciousness in which the nature of reality was often anthropomorphic or magical, with little parallels to our modern ideas of how the universe behaves. Also since much religious thought gains credibility from deeply ingrained cultural roots, and long-standing traditions which bind generations, it necessarily is a reflection of developments of mind that occurred hundreds, if not thousands of years in the past.

Some of the more ancient and less well-known religious traditions offer interesting insights and parallels to our modern astrophysical cosmology and quantum physics. A survey of religious and cosmological conceptions across the world reveals a remarkable diversity of understanding, which at times parallels modern physics and cosmology. From teaching a course on "Multicultural Cosmology" at Pomona College, we have surveyed many of these accounts of the creation, and a few examples of how ancient traditions offer insights into modern physical cosmology are below.

From the Chinese folk tradition of cosmology comes the conception of a creator god whose body becomes the physical universe in the act of creating it, thereby preserving the inseparable observer/observed from quantum mechanics. The emergence of the god from a "cosmic egg" parallels the emergence of our Big Bang from a primordial particle, and the mixture of yin-yang provides parallel with the nearly equal mixture of matter and anti-matter in the early universe:

"In the beginning twas a huge egg containing chaos, a mixture of yin-yang.. Within this yin-yang was Phan Ku, that which was not yet anything but which broke forth from the egg as the giant who separated chaos into the many opposites, including the earth and sky... When Phan Ku finally died, his skull became the top fo the sky, his breath the wind, his voice thunder, his legs and arms the four directions, his flesh the soil, his blood

the rivers, and so forth. The people say that the fleas in his hair became human beings.”

Phan Ku Chinese creation account, quoted from Leemer and Leemer, 1994.

The Hopi creation, along with many other Native American cosmologies, is intriguing in the way it incorporates thought, and a more nurturing metaphor for creating the universe than some of our major modern religions. Primary in the Hopi creation is Thought, and a pairing of the female and male creators Spider Woman and Tawa:

“Spider Woman and Tawa had the Sacred Thought, which was of placing the world between Up and Down within the Four Corners of the void that was the Eternal Waters. The Thought became the first song: “Father of all Life and Light I am,” sang Tawa. “Mother of all, receiver of Light and weaver of Life I am,” sang Spider Woman. “. . . “May the Thought live” intoned Spider Woman, and she formed it of clay. Together the first gods placed a sacred blanket over the new beings and chanted the song of life. The beings stirred into life.”

Hope Creation story as quoted from Leemer and Leemer, 1994.

One way to characterize the diversity of thought within these accounts of cosmology is analogous to the “Many Worlds” hypothesis of quantum mechanics. The “Many Worlds” hypothesis states that each instant of time offers many possibilities for particles, and the outcome we observe is an integral over these many paths. Likewise it is possible that as our human species evolves it develops many different worlds of religious and cosmological belief. With time the experience of our cultures and their descendents will integrate these belief systems into more refined religions and philosophies that respond to conceptual changes in their cultures.

The development of the modern picture of astrophysical cosmology and quantum mechanics has the potential to initiate profound shifts in the conceptual frameworks in which we regard the universe, reality and matter. It is fascinating to contemplate what new developments in religion and philosophy will accompany these developments. Perhaps future religions will evolve that will incorporate the profound discoveries of astrophysics and physics as central to their beliefs. This could include a commitment to egalitarian ideals, a recognition of the reality of the human condition imbedded in a complex matrix of particles, energies, and forces, in an incomprehensively vast ensemble of time and space.

To some degree the development of the Anthropic principle, and similar writings are moving us in this direction. The papers in this conference go further, and give hope that a clearer understanding of the sciences of physics and astrophysics

will only bring about a greater understanding of the human condition, the operating moral principles of the universe, and a new synthesis of science and religion which may guide our species' evolution into the future.

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