Information Storage and the Omniscience of God

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"The Religion that is afraid of science dishonours God and commits suicide." [Emerson]

Introduction

The topic of science and religion is a truly comprehensive subject, especially if one includes not only the major religious movements in the world but also currents of thought that do not specifically include the idea of a God. Even within the Judeo-Christian world, current literature in the arena of science and religion covers a wide range, from writers who accept mainly the results of science to those who rely mainly scriptures and traditional theology [see for example the collection of essays in Richardson]. Some of these writers seek a naturalistic, non-theistic philosophy of the world, while others attempt to harmonize modern scientific and religious ideas in a quest for a scientifically tenable theology.

Within this realm of thought, the present article perhaps is best described as in the field of "physical theology," a field of study whose origin is often attributed to a pioneering article by Freeman Dyson in 1979 [Dyson79; see also Dyson88]. Physical theology includes the study of constraints on theological ideas imposed by our knowledge of the universe, as well as physically observable consequences of theological postulates. The objective of this article is to point out what appears to be an inconsistency between the attributes of the traditional Christian God, as stated in the creeds of many Christian denominations, and certain scientific facts that govern information storage and transmission. In particular, we highlight an inconsistency between the assertion that (1) God is or consists of an undifferentiated "essence," and (2) God is omniscient. We seek a scientifically tenable solution to this problem, not merely a solution by "fiat."

The God of Traditional Christianity

The traditional Christian God is generally considered to be omnipotent, omniscient and omnipresent, as affirmed in the creeds of many Christian denominations. It is worth pointing out, however, that Biblical support for these doctrines is mixed. To begin with, these terms do not appear in the Bible, except for a single "omnipotent" in a highly poetic passage in Revelations [Rev. 19:6]. The Old Testament certainly has passages describing the great power and wisdom of God, but the compassionate and flexible natures of God are also portrayed. God has second thoughts about his creation in light of human wickedness at the time of Noah [Gen. 6:5-6], is willing to negotiate with Abraham over the fate of Sodom and Gomorrah on behalf of a handful of righteous people [Gen. 18:23-33], and instructs the Hebrews that they no longer need to consider children guilty because of the sins of their parents or ancestors [Eze. 18:1-32; compare with Deut. 23:2-4]. In the New Testament, Christ's teachings focused on righteous, humble and unselfish living, as exemplified by his Sermon on the Mount and numerous parables. Jesus described God as his "father" [Matt. 7:21; Mark 14:36; Luke 22:42; John 5:17]. He reduced the extensive Mosaic law to just two principles: love God, and love your neighbor as yourself [Matt. 22:39]. Paul focused on basic principles of Christian salvation, as exemplified by his "faith, hope and charity"

sermon [1 Cor. 13:1-13]. In short, while the Christian Deity is generally understood as an all-mighty and all-wise Being, from a strictly Biblical point of view this doctrine is comparatively flexible.

In the first few centuries after Christ, after lengthy debate, early theologians laid the groundwork for a systematic rational theology of God and Christ. These theologians were heavily influenced by Greek-Platonic philosophy, which viewed qualities of this world as mere shadows of ideals that exist in an unseen world. By 413 CE, God's omniscience was taken for granted in the writings of Augustine [Augustine, book 5, chap. 9]. By 1265, God's omnipotence, omniscience and omnipresence were prominently featured in Thomas Aquinas' *Summa Theologica* [Aquinas, part 1, chap. 7-14].

Even today, many Christians agree that God is infinite, eternal, omniscient, omnipotent, omnipresent, immaterial, and in general, exhibits perfection in all attributes. Possessing unlimited power, God can do anything that is not logically impossible (a qualification added by Thomas Aquinas). God is an undifferentiated, all-knowing, all-encompassing, all-pervading essence. God cannot be divided; God has no parts or pieces. Furthermore, God is the only non-contingent entity: God necessarily exists, while all other beings, objects, and forces are conditional upon God's creating and sustaining power. In this article, we examine one of the above-mentioned attributes, namely the notion that God is an undifferentiated essence, in view of the assertion that God is also omniscient.

God's omniscience is generally interpreted as knowledge of all things past, present, and future. Many have pointed out the difficulties in reconciling the doctrine of God's foreknowledge with the notion of free will or agency. In particular, if God (or any entity, for that matter, including a future super-powerful computer) has the ability to know future events in arbitrarily fine detail, then it is hard to argue against the conclusion that only one future course is logically possible. The resulting determinism has troubling inferences, such as that human free will is at best an illusion, that humans are not fundamentally responsible for their actions, and, even more radically, that the ultimate responsibility falls upon God. We should also add, in this context, that there are additional difficulties in reconciling the doctrine of perfect foreknowledge with modern physics. Specifically: (1) quantum mechanics asserts that it is fundamentally impossible for position and momentum (or other pairs of "conjugate variables") to be known to unlimited accuracy; and (2) chaos theory asserts that microscopic alterations or uncertainties of the present state can be amplified to produce arbitrarily large changes in the future course of the physical world. Combining these two well-established notions, many argue that it is impossible, within the realm of currently understood scientific laws, for the future to be predicted with unlimited precision—even if the general course of human events proceeds as anticipated, particular events beyond a certain level of detail cannot be foreseen.

Fascinating as these questions of God's foreknowledge are, we will not pursue them further in this article. Instead, we restrict ourselves to God's knowledge of the past and the present. We assume that knowledge is composed of data, facts, and ideas, all of which are, at the most basic level, forms of information. We will also assume that atoms, humans, and other physical entities in the universe are composed of bits of information. Some writers argue, by the way, that entities of the physical world are nothing but information or data, and that every human activity, including thinking and

possibly life itself, is merely a form of information processing, that could, at least in principle, be perfectly replicated in some sufficiently powerful computer [Tipler, pg. 124]. Indeed, this is the basic assumption of researchers in the field of artificial intelligence. But we will content ourselves with the somewhat more limited assumption given above.

Humans as Computers

An intriguing exploration into information processing and storage and its distant future possibilities is contained in the fascinating (albeit controversial) book, *The Physics of Immortality*, by Frank J. Tipler [Tipler]. How much information can be stored in the human brain? Gathering estimates from various sources, Tipler [pg. 22-23] makes the reasonable estimate that the human brain can store roughly 10^{15} bytes of data and can process data at a rate of 10^{13} operations per second. The superscripts here are the usual scientific shorthand for large numbers: 10^{12}, for instance, means a 1 followed by 12 zeroes, or in other words, one trillion. Tipler's book is controversial because of its highly conjectural extrapolation of the future of the Universe, past its state of maximum expansion, to its end at the "big crunch," or the "omega point," which event Tipler suggests will resemble the Judeo-Christian God in that it will be all-powerful and all-knowing. Unfortunately (or fortunately, depending on one's point of view), recent research indicates that the Universe is a "runaway" Universe, with accelerating expansion that will disperse the Universe into a state of arbitrarily low density [Livio, pp.1, 165-166; Barrow, pp.90-92]. Thus it appears that Tipler's scenario is simply not going to happen. Nontheless, Tipler's basic assertions regarding the information capacity of the human mind and the limits of information processing are on fairly solid ground.

How does the storage capacity and computational speed of humans compare with that of computers? At present, only a handful of the largest supercomputers possess the aggregate processing power and memory suggested above for the human brain. The NERSC-3 supercomputer at the research center of one of the present authors (DHB), for example, features a peak performance of 10^{13} floating-point arithmetic operations per second and has nearly 10^{13} bytes of main memory (and approximately 100 times this much disk memory). But Moore's Law, the remarkable phenomenon wherein semiconductor devices (and computer systems) double in capacity and power roughly every 18 months, has continued unabated for nearly 40 years, with no end in sight. Thus it seems inevitable that even desktop systems will have this much data capacity and computing power within ten to fifteen years.

In 1981, Jacob Bekenstein [Bekenstein] derived equations that allow the calculation of the maximum possible data that can be contained in any given space or body, including all quantum mechanical energy levels. This number, called the Bekenstein bound, is huge for most objects. For a human being, the bound is roughly 10^{44} bytes, an outrageously large number (although many scientists and mathematicians regularly deal with such numbers). This means, for example, that a future computer with this much memory could, in principle, store the equivalent of an entire human body, including its brain and memory, as data (because there are only 10^{44} physically possible states in a human-sized volume). What's more, this figure is a theoretical upper bound—a computer should be able to replicate the body's (and brain's) complexity with far less data. In any event, the point we emphasize here is that this figure is a finite, bounded value, derivable from basic principles of quantum theory.

In the same vein, viewing the Universe as a physical system that works as a computer, one can estimate, within a factor of 10, the computational capacity of the entire Universe, or at least that part of the Universe (the "pocket Universe") that is within our horizon. During its entire lifetime (about 10^{10} years since the big bang), the Universe as a whole can have performed 10^{120} elementary quantum logic operations on 10^{90} bits, counting all quantum states (which number could rise to 10^{120} if all gravitational degrees of freedom are accounted for) [Lloyd]. Again, this is not an attempt to accurately measure this count, only to provide a reliable upper bound for the computational capacity of the Universe.

Data Storage

Computer scientists conceive of data in terms of familiar binary digits (bits), such as 10110101 (a string of eight bits such as this constitutes one byte). Data can be stored in almost limitless ways as long as there is a two-state system. In fact, any system that can differentiate between two states can in principle store binary information and thus data. Some examples of physical phenomena that can be exploited for data storage include: (1) electrochemical impulses; (2) positive and negative charges in an electric circuit; (3) tiny dots of magnetic north or south on a tape or disk surface; (4) particles with spins up or down; (5) the quantized magnetic flux of a supercomputing loop; (6) photons in a fiber optic cable; (7) temperature differences in material objects; (8) velocity differences among molecules or atoms or electrons; (9) polarization of photons or electrons; and (10) holographic patterns of refraction in a physical medium. Indeed, several of the schemes listed in the previous sentence have actually been realized in commercial data storage devices and biological organisms, and some others are being considered for future computer technology. Computer scientists and engineers generally choose the method that stores the most data most efficiently at the lowest energy cost, since any storage or retrieval of data requires energy.

In summary, the storage and transfer of information require: (1) an energy source and (2) a system with distinguishable states. These assertions do not at all depend on our present level of technology. They appear to be much more general principles, and indeed, they are expected to be valid anywhere in our universe, according to all known physical laws.

As an example of information storage in the real world, let us consider the radiation from an ideal radiator. As scientists have known since the work of Einstein and Planck, light cannot be infinitely divided but on the smallest scale consists of tiny packets called photons. Planck further showed that the dependence on the temperature of the emitter and the wavelength or frequency of the radiation from an ideal radiator (a body that absorbs and re-radiates all energy falling upon it) can be described to any desired accuracy by a relatively simple mathematical function, the so-called blackbody function, usually written $B(\nu,T)$. What appears to be a complicated radiation field can be fully described by $B(\nu,T)$, and no more information is stored in it or can be obtained from it.

One example of the blackbody function in the Universe is the cosmic microwave background (CMB) radiation—the radiation from the sky that is very nearly homogeneous and isotropic (ie, the same in every direction). Outside of empty space (the "vacuum"), the CMB radiation is the best-known example of an omnipresent entity in the entire physical universe. It is the remnant of the original radiation emitted when atoms formed and matter and radiation decoupled some 300,000 years after the big bang. So smooth is the background distribution of this radiation that any

deviation over the sky amounts to less than one part in 100,000, as recently measured by the Cosmic Background Explorer (COBE) satellite.

Any ensemble of objects (molecules, electrons, etc.) in disordered motion will, through frequent mutually elastic (bouncing) collisions, assume an isotropic velocity distribution that is uniquely specified by that distribution and the temperature alone. A single particle, although it has a unique velocity and position, carries no additional information. Furthermore, the whole ensemble carries no further information because it is a function of temperature only through the specified velocity distribution, the Maxwellian (equilibrium) velocity distribution, which describes the velocity field of any group of particles in thermal equilibrium as a function only of the temperature.

Consider, then, a flux of high-velocity particles of any sort. Because they have unique energy and direction, they carry information and can therefore be used for data storage. Let them interact, even briefly, with the thermal bath of particles in a Maxwellian distribution described above (many gases in the universe, whether in the earth's atmosphere or in the distant stars, are in thermal equilibrium), and their velocities will be randomized in both direction and magnitude. Although the whole bath may gain a bit in temperature, these particles will now be indistinguishable from the rest. They have lost whatever information they once had.

Another way to lose information is through a black hole. Information in the form of atoms, gas, stars, comets, unlucky astronauts, or whatever falls into a black hole is irretrievably lost after it falls past the Schwarschild limit (the limit in space within which even a photon cannot escape). A black hole is one of nature's simplest objects; an electrically neutral black hole is describable by mass and angular momentum alone. That's all. All other information is lost forever. Even when a black hole evaporates, as black holes eventually will, no information will be regained, according to our current understanding of the physics involved.

Now consider a smooth cloud of neutral, isotropic, homogeneous matter. It contains no more information than its mass, size, shape, chemical composition, density, and temperature. Consider further a much larger cloud, a cloud so large that its size is no longer of interest, consisting of some isotropic, homogeneous, and undifferentiated essence. The only information it contains, besides chemical composition and density is possibly its temperature. It is useless for data storage.

Looking to the Future

With the convenience of radio, television, digital cell phones, and the Internet, most of us take for granted the storage and transfer of large amounts of data. We think nothing, for instance, of sending a photo with a million bytes of data to a family member. However, data transfer has significant costs in both space and energy, and these conveniences have become commonplace only because of the availability of cheap electricity. With the exception of nuclear energy, the Sun is the ultimate source of all the energy we use. In a billion years or so, as it begins to convert the last of its core hydrogen to helium, the Sun will slowly become a red giant star, and its luminosity will increase by a factor of several thousand. Such a prodigious output of energy may permit grand adventures, but, unfortunately, it will also doom life on Earth as we know it. Let us suppose for the moment that human life is somehow able to escape that catastrophe and spread to planets around other stars. What are the ultimate sources of energy for data storage?

If the Universe is a closed system and will one day collapse into a super-hot, super-dense ball (the "big crunch" or "omega point"), this conclusion would appear to doom all life and information storage. However, if the collapse is not isotropic (the same in all directions), immense amounts of energy from the differences in gravitational forces in different regions (called "gravitational shear") might be used by a super-intelligent civilization to store and transfer data [Tipler, pp. 136-140]. However, as we mentioned above, it appears from recent supernova data that the expansion of the universe is not slowing down; instead it is accelerating—evidently we live in a runaway universe [Livio, pp.1, 165-166; Barrow, pp. 290-292].

The full implications of these discoveries for future life, and for future information processing of any type, are being explored at the present time by cosmologists and physicists. But the basic principles and methodology behind these ruminations are the same: Scientists estimate the amount of information processing required by the human mind, and try to conceive the mechanisms and medium that might this permit processing to be performed. As always, some differentiation into multiple states, either in composition, velocity, temperature, photons, or force fields, is essential, as is an energy source. As before, without differentiation of some type, there can be no data storage or data processing.

God as Computer

Let us now consider the doctrine of God's omniscience. As we have noted above, many mechanisms have been proposed, consistent with the known laws of nature, to store and transmit information, but they all require at least a two-state system. It appears fundamentally impossible for any one-state system to be a repository of data. More generally, a perfectly undifferentiated, completely homogeneous, immaterial essence (either mass or energy field) cannot be a repository of data.

This is the heart of the difficulty. If God is a "perfectly undifferentiated, completely homogeneous, immaterial essence," and if God works in any sense within the realm of physical law, then it follows that God can neither store nor process any information, much less be "omniscient."

How can one address this difficulty? One can conceive that temperature differences or velocity gradients exist in God, but this goes against the traditional notion of an omniscient, omnipresent, immaterial God. Another solution is to identify God with the Universe (or the vacuum), but this is a pantheistic theology, distasteful to many. God then would be able to compute as well as the Universe (or the vacuum) computes, and God would be as omniscient as the Universe, which indeed contains a huge amount of knowledge (see estimate above). But such a God would also be exactly as caring and compassionate as is the Universe, and would answer prayers to exactly the extent they are answered by the Universe–no more, no less! This does not seem much like the God worshipped as "our Father in heaven" by Jesus.

Omniscience by Fiat?

Some defenders of the traditional doctrine of God's omniscience may respond to this argument by simply declaring that God is omnipotent and thus omniscient, in the sense of residing and operating

completely outside the confines of the Universe and the natural laws that govern our Universe. In short, they may assert omnipotence and omniscience by fiat: God can store knowledge, even an infinite amount of knowledge, without any plausible physical storage mechanism or medium. This is because God's ways are not ours, and our finite mortal minds cannot possibly hope to comprehend the means employed by this supreme Being. Against such reasoning there is no counter argument.

Needless to say, such reasoning is tantamount to a complete retreat from the worthy objective of finding a scientifically tenable theology. We are required, by this line of thinking, to posit a Being whose nature is completely apart from this universe and not detectable or comprehensible by any conceivable means of scientific inquiry. Such a notion is, by definition, not falsifiable and thus not a scientific notion in any degree. It is even less like the New Testament God than the pantheistic Deity.

Such thinking also has overtones of the "God the great deceiver" theology. This is the distasteful notion that God has created the Universe, but now has removed himself from our view, and further has deliberately hidden his existence from our means of rational thought. Such notions have been advanced in "creationist" literature—according to some writers, the reason the earth appears by scientific tests to be very old, in spite of its presumed instant fiat creation a few thousand years ago, is that God created it this way as a test of our faith [Whitcomb and Morris, pg. 233-239]. Surely there are better solutions than this to the questions of geology, evolution and creation!

And surely we trust that there is a better solution than fiat omniscience to the issues raised here. It is a scientifically tenable solution that we seek.

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