An Intelligible Universe

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When Galileo first pointed his telescope at the heavens and discovered four of the moons of Jupiter, he was inaugurating a great era of human exploration of the cosmos. Optical telescopes would eventually improve beyond his wildest expectations and invisible parts of the spectrum would also be made accessible through clever developments in instrumentation. In due time, all this would yield profound human understanding of extraterrestrial realms, exhibiting wonderful order and fertile history. This great intellectual quest has taken us far beyond the solar system and beyond the Milky Way itself, which we now know is simply our local galaxy, whose composition as a multitude of stars was another of Galileo's great astronomical discoveries. Today, scientists can speak of a vast observable universe, composed of 10^{22} stars. They can tell us much about the 13.7 billion year history that has followed the universe's springing forth from its origin in the initial singularity of the Big Bang, and they have understood many of the processes by which that primeval ball of energy has expanded and evolved to become the home of saints and scientists.

These are very remarkable achievements which, I believe, tell us significant things about the kind of world it is that we inhabit and what kind of beings we humans are. In the primeval dawning of human self-consciousness, the universe became aware of itself, perhaps the most astonishing development that we are aware of in that 13.7 billion years of cosmic history. The universe has proved not only to be extremely fruitful, but it is also deeply and wonderfully intelligible, affording continual intellectual delight to those who have been privileged to be the explorers of its

marvellous order. Is this all just an incredible piece of luck, or does it have some deeper meaning?

No doubt, survival necessity offers an explanation of why evolutionary process has shaped our brains in such a way that we can make sense of the world of everyday experience. If we could not figure out that it is a bad idea to step off the top of a high cliff, we might not be around for very long. However human powers to understand the world go greatly beyond anything needed for mundane survival. In an astonishingly creative leap of the human imagination, Isaac Newton was able to see that the same force that makes the high cliff dangerous is also the force that holds the Moon in its orbit around the Earth and the Earth in its orbit around the Sun, to discover the mathematically beautiful law of universal inverse square gravity, and in terms of that law to explain the behaviour of the whole solar system. It was a great achievement, but one that had no direct utility for matters of everyday survival. After all, the famous fictional detective, Sherlock Holmes, feigned indifference about whether the Earth went round the Sun or the Sun went round the Earth, saying what did it matter for his daily work as a detective?

Human access to intelligibility has proved to be remarkably extensive, far beyond the limits of what might be derivable from ordinary experience. It embraces not only the extraterrestrial reality of the universe as a whole, an immense realm of cosmic curved space-time, but it also includes the subatomic world of quantum physics, The latter constitutes the foundational fabric of the physical universe, but its nature is remote from any immediately discernable impact upon mundane matters and for its understanding it requires the use of ways of thinking that are strange and totally counterintuitive in terms of everyday expectation. Who could have supposed that it was possible for something sometimes to behave like a wave (that is, spread out and

flapping) and sometimes like a particle (that is, like a little bullet)? Yet, as we all know, that is the way that light has actually been found to behave. Without the stubborn nudge of nature forcing us to the discovery, who would have thought that an electron could be in a state where it is both 'here' and 'there'?

The universe has proved to be astonishingly transparent to our scientific enquiry. Scientists agree that this is so and respond by eagerly exploiting the opportunities that this wonderful fact affords. But, speaking as scientists they can offer no explanation of why this should be the case. Yet it would surely be intolerably intellectually lazy simply to treat this remarkable fact as it were just a happy accident or an inexplicable brute fact. Albert Einstein once said that the real mystery of the universe is its comprehensibility. The pursuit of science is motivated by the human thirst for understanding, and this quest should not be allowed to halt at the frontiers of science itself. If the intelligibility of the universe is to be made intelligible, that search for understanding will certainly take us beyond the self-limited domain of scientific insight alone.

And the mystery is even deeper than that, for it has turned out that the ultimate key to the unlocking these cosmic secrets is provided by that seemingly most abstract of academic subjects, mathematics. It is an actual technique of discovery in fundamental physics to seek theories whose mathematical expression is in terms of beautiful equations. Mathematical beauty is a somewhat rarefied form of aesthetic experience, involving the discernment of qualities such economy and elegance and that of being what the mathematicians call 'deep' – that is to say very extensive consequences are found to flow from a deceptively simple seeming starting point. This form of beauty is something that the mathematically literate can recognise and, most significantly, that they can agree about. This quest for mathematical beauty is no act of aesthetic

indulgence on the part of the physicists, but it is a proven heuristic technique which, over three centuries, has time and again led to many fundamental discoveries in physics. The greatest physicist whom I have known personally was Paul Dirac, one of the founding figures of quantum theory and undoubtedly the greatest British theoretical physicist of the twentieth century. He made his many great discoveries by a relentless and highly successful quest for mathematical beauty. Indeed, he once said that it is more important to have mathematical beauty in your equations than to have them fit experiment! Of course, Dirac did not mean that ultimately empirical adequacy could be dispensed with, but if it was not apparent at first sight, then there were at least some possibilities that might still save the day. Maybe you had made an incorrect approximation in seeking to solve your equations, or maybe the experiments were wrong (we have known this happen more than once in physics), but if your equations were ugly … really there was no hope! The whole history of fundamental physics testified against the possibility of their being right.

Dirac's Nobel prize-winning brother-in-law, Eugene Wigner, once expressed in epigrammatic form the challenge that this role of mathematics presents to us. He asked, 'Why is mathematics so unreasonably effective?' Why is it that some of the most beautiful patterns that the mathematicians can conceive of in the course of their abstract logical thinking, are found actually to occur, instantiated in the structure of the physical world around them? What links together in this remarkable way the reason within (our mathematical thinking) and the reason without (the order of the intelligible universe)? Wigner said that this effectiveness of mathematics was a gift that we neither deserved nor understood. Well, I don't know whether we deserve it, but I would certainly like to understand it. It would be intellectually lazy not to seek to answer Wigner's question.

This role of mathematical beauty in physics would not have surprised Galileo, who famously declared that the book of nature was written in mathematical form. Of course, while the equations of fundamental physics are always found to be beautiful, not all beautiful equations will be found to describe nature. Mathematical beauty is a necessary, but not a sufficient, condition for deep physical theory. The reason that the physicists put their trust in the actual equations thus chosen is because they turn out to demonstrate a long-term fertility of explanation which is very persuasive that they are truly describing significant aspects of the ways things really are. Dirac's most remarkable discovery was his celebrated relativistic equation of the electron (which is inscribed on his memorial tablet in Westminster Abbey). He wrote it down as a mathematically elegant way of combining quantum theory and relativity, but as soon as he had done so he unexpectedly discovered that it implied that the electron's magnetic properties were twice as strong as classical thinking would have expected them to be. In fact, this was already known experimentally to be the case, but no one had known why it should be so. A little later, Dirac also discovered that his equation implied the existence of antimatter, a previously totally unknown possibility. Such sustained and unforced fruitfulness strongly endorses the view that mathematical beauty is a heuristic tool for real discovery and not a mere indulgence in aesthetic fancy.

Thus the universe has proved not only to be astonishingly rationally transparent, but also astonishingly rationally beautiful. As a recompense for the labours of research, the cosmos offers physicists the reward of wonder at the marvellous order revealed to their enquiry. These facts surely call for some form of explanation, and I have already stated that this will have to be found outside the domain of science itself, since it simply accepts the laws of nature as the unexplained basic brute fact from

which it then seeks to derive its understanding of cosmic process. I suggest that these laws of nature have so remarkable a character of accessibility and beauty that they seem to point beyond themselves, and to demand a further and deeper context of intelligibility than that which science by itself can provide.

So, 'Why is science possible in the deep way that it is?' And 'Why is mathematics so unreasonably effective?' These profound metaquestions, arising from scientific experience but taking us beyond science itself, call for a response. Such issues are too deep to receive an answer of the indisputable kind that would imply that all are logically forced to agree without any further argument. There is no knockdown response on offer, but I wish to maintain that the most satisfying and intellectually persuasive answer that I know is to be found in the theological recognition of the universe as a divine creation. One could summarise the transparent rational beauty of the cosmos as revealing to us a world whose nature is shot through with signs of mind. I am proposing that we take absolutely seriously the idea that it is indeed the Mind of the Creator that lies behind the deep order of the universe. The unreasonable effectiveness of mathematics, the unexpected consonance between the internal reason of our minds and the external reason of the physical world, can then be understood to arise from the fact that our mental abilities and the structure of the laws of nature have a common origin in the rationality of the Creator, who is the ground of the existence of both human nature and the physical world that we inhabit. In my opinion, science is possible in the profound way that it has proved to be, precisely because the universe is a creation and we are - to use an ancient and powerful phrase - creatures made in the image of our Creator. Theistic belief makes the intelligibility of the universe itself intelligible.

This approach to the intelligibility of the universe represents a revived and revised form of natural theology[1]. The latter discipline is the attempt to learn something of God through the general exercise of reason and the inspection of the world, complementing and contrasting with the approach of revelational theology, which appeals to specific acts of divine disclosure, believed to have occurred in the course of history. I believe that an adequate theology needs to seek insight from both these sources, but here I am concentrating on natural theology, since it offers a valuable bridge between the insights of science and the insights of religion. I strongly believe that these two great human quests for truth are consonant with each other, rather than being in mutual conflict. They are friends and not foes, fundamentally because they both share in the great human quest for truthful understanding. It is important to recognise that this new natural theology is significantly revised from the form that it took in the eighteenth and early nineteenth centuries at the hands of people such as William Paley. Their line of thought sought to appeal to the great aptness of living beings to life in their environment and it made play with such matters as the optical system of the eye, whose complex existence was asserted to be evidence for the direct work of an intervening divine Designer. Of course, this form of argument was given its death blow by the evolutionary insights of Charles Darwin, whose great theory showed how the patient sifting and accumulation of small differences over very long periods of time could lead to the appearance of design without calling for the direct intervention of a divine Designer. With hindsight we can see that Paley and his associates were making a fundamental mistake about the nature of the relationship between science and religion. We have every reason to believe that scientifically stateable questions will ultimately receive scientifically stateable answers, even if some of these answers may prove very hard to find – for example we are still ignorant

of the biochemical processes by which life first began. However, we also have every reason to believe that there are many questions that are meaningful and necessary to ask and to seek to answer, which lie outside the self-restricted field of scientific enquiry. We have been considering two such questions when we asked Why is science possible? Why is mathematics so unreasonably effective? These are metaquestions, arising from scientific experience but necessarily taking us beyond science's own power to respond. The new natural theology does not seek to rival science within the latter's legitimate domain, but its aim is to locate science's insights within a broader and deeper context of intelligibility. Cosmic intelligibility is then itself made intelligible.

If the universe is indeed a divine creation, it is not to be expected that it will be full of objects clearly stamped 'Made by God'. The Creator is more subtle than that. What we may expect is that there will be hints of the presence of a divine Mind behind cosmic order and a divine Purpose behind cosmic history. The Creator is not a kind of celestial Artificer, repeatedly intervening to construct new forms of creaturely life, but God is the One who has endowed the given physical fabric of the world with an inbuilt potentiality that will lead to a designedly fruitful history. That potentiality has been made actual through the specific contingencies of evolutionary process. As Darwin's clergyman friend, Charles Kingsley, said, the Creator has chosen to make a universe so endowed with fertile potentiality that creatures have been allowed, to an appropriate degree, 'to make themselves'.

If the Creator is indeed the God of love, as Christian theology proclaims, then surely the creation will not simply be a divine puppet theatre in which God pulls every string. The gift of love is always the bestowal of an appropriate degree of freedom on the objects of love, allowed to be themselves and to make themselves.

This means that an evolving world, whose God-given potentialities are explored and brought to birth through a kind of unfolding act of continuous creation in which Creator and creatures collaborate, is surely a more valuable world than a ready-made creation would have been. Yet that world has an inescapable cost, an unavoidable shadow side. The shuffling explorations of evolutionary contingency will inevitably result in blind alleys and malformations as well as in great fruitfulness. Genetic mutation in germ cells will give rise to new possibilities for life, but in somatic cells it may lead to malignancy. The anguishing fact of cancer in the world is not due to callousness or incompetence on the part of the Creator, but it is the necessary cost of a creation in which creatures are allowed to make themselves. This insight offers theology some help as it wrestles with its greatest problem, the existence of evil and suffering in a world said to be the creation of a good and powerful God. It is important to recognise what is meant by calling God 'almighty'. It does not mean that the deity can do absolutely anything, but rather that God can do whatever God wills, though God will only will what is in accordance with the divine nature. God's acts are not externally constrained, but they are internally constrained by consistency with the divine character. The rational God will not decree that 2+2=5; the loving God will not act as a Cosmic Tyrant holding all under tight control. Within certain limits, creatures will be allowed to be themselves and to make themselves. Just as the free-will defence, based on the value of the gift of human freedom, offers some help with understanding the possibility of moral evil, so there is a parallel 'free process defence'[2] asserting the value of a creation in which creatures play their own roles in bringing to birth its inbuilt fruitfulness, despite its necessary shadow side.

I think these insights are of considerable importance for theology. I have been speaking of the rational beauty that physicists encounter in their exploration of reality,

but at the level of biology a more ambiguous picture seems to emerge, characterised not only by fruitfulness but also by wastefulness. It is a tale, not only of the increasing rich complexity of being, but also of a chain of extinctions. Without some theological response to this problem, the surd of animal and human suffering threatens the claim of cosmic intelligibility. I do not assert that all difficulties are removed by this theological interpretation of evolutionary process, but one can begin to see that the suffering of creation is not gratuitous, something that would have been easy for the Creator to remove without prejudicing other divine gifts and purposes.

Of course there is an inescapable degree contingency in the outcome of an evolving creation. Its history will not be like the performance of a fixed score, but it will resemble an unfolding improvisation in which both Creator and creatures act in concert to contribute to the development of the grand fugue of creation. I do not believe that the specificity of five-fingered *homo sapiens* was decreed from all eternity, but equally I do not believe that the emergence of some form of self-conscious, God-conscious beings was simply an incredibly happy accident.

The insights of the cosmic anthropic principle[3], the exquisite fine-tuning of the given character of fundamental physical law which was necessary if the universe were to be capable of evolving the richness of carbon-based life, would be a familiar and striking example of how there can be intrinsically designed potentiality built into the fabric of the world without removing the gift of creaturely freedom by a rigid specification of all that must happen in the course of cosmic history. For example we know that many of the elements that are essential for the biochemical possibility of life can only be made in the interior nuclear furnaces of the stars. Every atom of carbon in our bodies was once inside a star. We are people of stardust, made of the ashes of dead stars. This has only been possible because there is a resonance in carbon

at exactly the right energy to permit viable amounts of carbon to form in the course of these intricate stellar processes. If the laws of nuclear physics had been only a little bit different, either there would have been no resonance at all, or one at the wrong energy, and the immensely fertile character of carbon-based life would have been impossible in such a world. The process of nucleosynthesis in the stars proceeds by a beautiful and very delicately balanced chain of reactions, whose unravelling was one of the great astrophysical discoveries in the second-half of the twentieth century. A universe that is capable of evolving carbon-based life has to be a very special universe indeed in the given specificity of its physical fabric. All scientists agree that this is so. Theists will see this fine-tuning as part of the Creator's endowment of creation. Those who wish to avoid such a conclusion are driven to the prodigal and rather desperate stratagem of hypothesing the existence of a multiverse, an immense portfolio of different worlds, each observationally separate from the others, and each with different laws of nature, in which our universe is, simply by chance, the one capable of evolving carbon-based life.

The Creator's work need not be confined to providing the right ground rules that will permit the fertility of cosmic process. One may also believe that divine purpose has been providentially at work within the unfolding history of the universe, without having to appeal to repeated divine interfering interruptions of the processes of creation. The latter idea is, in fact in danger of theologically unintelligibility, with its implication of an intervening God acting against the divinely ordained and sustained order of creation. I believe that a careful analysis shows that science has not established the causal closure of the world on its own reductionist terms alone. There is an actual openness in the causal structure of the world that permits the acts of agents, whether human or divine. I believe that that God does indeed interact

providentially with creation's history (a theme that would require another lecture to develop)[4], but I also believe that the Creator, who is the Ordainer of the laws of nature, acts as much through natural processes as in any other way. The balance between the way in which divine and creaturely action together bring about the future is the problem of grace and freewill, now written cosmically large.

Science is one sector of the great human quest for truthful understanding, attained through well-motivated beliefs about the nature of reality. The question of truth is as central to religion as it is to science, so that theology is also a sector of this grand human endeavour. Of course there are differences between the characters of the two enquiries. Science limits itself to encounter with an impersonal dimension of reality in which repetition of experience is possible, giving it the great secret weapon of experiment. If you doubt what a scientist tells you, then in principle, and sometimes in practice, you can repeat the experiment for yourself. This enables science to attain an impressive degree of intersubjective agreement. Yet we all know that there are many other dimensions of reality – broadly speaking the domain of personal or transpersonal encounter – in which repetition is not possible, since all such individual experience possesses a degree of uniqueness. We never hear a Beethoven quartet twice in exactly the same way, even if we replay the same disc. In the realm of the personal, whether in art or music, human relationships or encounter with the transpersonal reality of God, truthful understanding has to be gained through commitment and trust, rather than by putting matters to repeated testing. If I am always setting little traps to see if you are my friend, I shall soon destroy the possibility of friendship between us, since this must be based on mutual trust and respect. In the domain of the personal there is an irreducible uniqueness of

experience, and issues of meaning and value, which science by its own self-definition brackets out, are in fact paramount.

Despite these striking differences between science and religion, there is also sufficient commonality between the two in their search for truthful understanding for there to be some lessons that are common to both. If science teaches one anything about the world it is that reality is often surprising beyond our rational powers to anticipate. Who in 1899 would have supposed that something could sometimes behave like a wave and sometimes like a particle? Any philosopher could easily have 'proved' the impossibility of such an oxymoronic combination of properties. Nevertheless, that is how light has actually been found to behave and the subsequent discovery of quantum field theory has made this strange behaviour intelligible to us. Quantum theory is based on the Superposition Principle, stating that quantum states can be formed by the addition of possibilities which Aristotle and common sense would say could never be mixed together. For example, we have already noted that an electron can be in a state that is a mixture of being 'here' and being 'there'. This fact is the origin of the unpicturable cloudiness of the fitful quantum world. Superposition allows a middle term of a kind undreamed of by Aristotle (possibly here, possibly there), and this implies that a specifically new kind of quantum logic applies to quantum entities. It turns out that the wavelike states of light (technically, those with a definite phase) correspond to states with an *indefinite* number of particles, something that would be impossible in the clear world of classical physics, where one would simply look and count how many particles were present. The English biologist J.B.S Haldane, commenting in the late 1920s on the discoveries of his physicist colleagues, said that the universe had not only turned out to be queerer than we thought, but

queerer than we could have thought without the help of the actual promptings of nature.

The quest for intelligibility has to be flexible, willing to conform itself to the actual nature of the reality encountered and not constrained by prior assumptions about the necessary character of rationality. In fact there is no universal form that rationality has to take, but the right manner of thinking is determined by the nature of what it is that we are trying to think about. Consequently, the natural question for a scientist to ask, within science or beyond it, is not 'Is it reasonable?', as if we thought we knew beforehand the shape that reason had to take. Instead the natural question for the scientist is one at once more open and more demanding in its character, 'What makes you think that might be the case?' This form of question does not seek to impose prior conditions on the character of an acceptable answer, but if something strange and unexpected is being asserted, it will only be accepted if motivating evidence is presented for that belief.

I believe that this is the right question to ask in every sector of the quest for truth, including theology's search for religious truth [5]. If the physical world has proved surprising beyond our prior expectation, it would scarcely be strange if that were not also true of that world's Creator. At the heart of Christian belief lies the duality of human and divine natures in Jesus Christ, a belief even more counterintuitive to natural expectation than the wave/particle duality of light. Nevertheless, I believe that there is motivating evidence to support this belief, though this is not the place to pursue that particular matter, a task that I attempted in my Gifford Lectures[6].

Instead, I turn to another cousinly relationship between science and theology which I believe to be of significance. The strange character of the quantum world, in which, for instance, electrons can simultaneously be both here and there, and they are part of

a reality that is partly veiled from us by Heisenberg uncertainty, has given rise to much philosophical discussion of the degree of reality to be assigned to such elusive entities. Some have suggested that quantum physics is no more than an instrumentally useful manner of speaking about phenomena, and that actual access to reality is limited to the clear perceptions available to us at the macroscopic level of classical measuring apparatus. However, almost all physicists have resisted this dismissal of quantum reality, in my view rightly believing that there really are electrons, and even such intrinsically hidden entities as confined quarks. Reality is not to be identified with a naïve objectivity of a classical kind. To suppose the contrary was the mistake that Einstein made and which led to his persistent hostility to the quantum theory come-of-age, of which he had been the grandfather. Of course, the quantum world cannot be known with the clarity of Newtonian physics, but it has to be met on its own terms, respectful of its Heisenbergian cloudiness. Just as there is no single form that rationality has to take, so there is no single form that epistemology has to take either. Entities have to be known in accordance with their natures. We can know the microworld of quantum physics in one way, the macroworld of classical physics in another way, persons in a third way and the transpersonal reality of God in a fourth way.

How then is the reality of the quantum world to be defended against its critics? I believe that it is intelligibility that gives us the key[7]. We believe in the reality of photons and electrons because that belief gives us satisfying understanding of a great swathe of more directly accessible phenomena, from the periodic table of chemistry to the behaviour of devices such as the laser. In an analogous way, religious belief in the reality of the unseen God can be defended because it makes intelligible great swathes of well-testified spiritual experience, as well as affording us an understanding of the

deep intelligibility of the universe in the manner that we have been exploring. A theologian who placed the criterion of intelligibility at the heart of his theological method, was Bernard Lonergan. He wrote in the tradition stemming from Thomas Aquinas, which sees the search for understanding, pursued with vigour and without reserve, as being ultimately the quest for God. I shall end with one of my favourite quotations from Lonergan: 'God is the all-sufficient explanation, the eternal rapture glimpsed in every Archimedean cry of Eureka'[8]. That speaks both to the scientist and to the religious believer in me.

Notes

1. J.C.Polkinghorne, *Science and Creation* (2nd ed.), Templeton Foundation Press, 2006, chs 1and 2.
2. J.C.Polkinghorne, *Science and Providence* (2nd ed.), Templeton Foundation Press, 2005, pp. 77-8.
3. See, for example, R.D.Holder, *God, the Multiverse and Everything*, Ashgate, 2004.
4. J.C.Polkinghorne, *Belief in God in an Age of Science*, Yale University Press, 1998, ch.3.
5. Polkinghorne, *Theology in the Context of Science,* SPCK/Yale University Press, 2009.
6. J.C.Polkinghorne, *Science and Christian Belief*, SPCK, 1994/*The Faith of a Physicist*, Fortress, 1996, chs 5-7.
7. See, J.C.Polkinghorne, *Quantum Theory: A Very Short Introduction*, Oxford University Press, 2002, ch. 6.
8. B.Lonergan, *Insight*, Longman, 1958, p. 684.