Can We Comprehend the Cosmos?

A debate between

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The papers published here are the presentations made during the debate "Can We Comprehend the Cosmos?", held at the University of Victoria on 5 February 1998, sponsored by the Royal Society of Canada / La Société royale du Canada.

Both participants in the debate, Dr Alan Batten and Dr Harold Coward, are Fellows of the Royal Society of Canada. Dr Batten is an astronomer at the Dominion Astrophysical Observatory in Sidney, BC, and Dr Coward is Director of the Centre for Studies in Religion and Society and Professor of History at the University of Victoria.

During the debate Dr Batten made the first presentation, Dr Coward the second. A final comment by Alan Batten follows. Dr Batten expresses the belief that science helps us explain the cosmos without diminishing our wonder of it. Dr Coward, a scholar of Eastern religions, believes full comprehension of the cosmos is not possible through concepts. Their joint presentations are intended to provoke and enlighten.

This publication is dedicated to the memory of
Dr Louise Fothergill-Payne, FRSC

I want to introduce my topic with a quotation from *La Valeur de la Science*, written nearly a century ago by the great French mathematician and mathematical astronomer Henri Poincaré, who was considering a question we still have not completely solved today: how to convince politicians to spend large sums of money on the building of astronomical observatories. He briefly considered, and rejected, an appeal to the considerable practical value that astronomy then had for oceanic navigation. Politicians, he felt, would respond to a more intellectual argument (his cousin later became President of France) and I offer my own translation of that argument (with emphasis added):

> Astronomy is useful because it raises us above ourselves; it is useful because it is great; it is useful because it is beautiful; that is what we should say. It is astronomy that has shown us how small the human body is and how great the human spirit, since this brilliant immensity, in which our bodies are only obscure points, can be completely embraced by our minds, which can also enjoy its peaceful harmony. Thus we become aware of our strength, and that can never cost too much, because that awareness makes us stronger.
>
> But what, above all, I wish to show you is the extent to which astronomy has promoted achievements in other more directly useful sciences, because *it is what has made our souls able to comprehend nature.*

That sounds like a scientist's credo and like all creeds is rather triumphalist in tone. Some of you may well think it typical scientific arrogance but in the context of the whole book it would sound different and I want you to concentrate on its four underlying themes rather than the precise words. The first theme is implicit: that a real cosmos exists "out there", independently of ourselves. The second is quite explicit: that we can comprehend this cosmos. Poincaré had no doubts about that, although elsewhere in the book he qualifies that claim. The third theme is also explicit: that there is something in the cosmos best described by words like beauty and harmony to which we can respond. Poincaré

meant something more than the beauty of the starry sky (which could still be seen, even from the cities of his day) or even the weird and haunting beauty shown in Hubble-telescope photographs (which he never saw). He meant a mathematical harmony, especially as revealed in the laws governing the motions of bodies in the solar system – his special area of research. This brings us to the fourth theme, implicit in this passage but quite explicit in the book: that it is mathematics that enables us to enjoy the harmony and the beauty and which, therefore, enables us to comprehend, in some measure, the cosmos in which they are found. These four themes are related and recur throughout Western intellectual history. The book of Nature, it is sometimes said in a paraphrase of something Galileo wrote nearly 400 years ago, is written in the language of mathematics; and the idea goes back at least to the time of Pythagoras, some 2,500 years ago.

Pythagoras or the Pythagoreans were struck by the simple numerical relationships between the lengths of vibrating strings that emitted notes whose combinations were pleasing to the human ear. They sought and professed to find similar relationships between the motions of the planets: thus arose their doctrine of the music of the spheres. It is easy to make fun of this doctrine, but Shakespeare understood and expressed its deeper meaning very well:

> How sweet the moonlight sits upon this bank!
> Here will we sit and let the sounds of music
> Creep in our ears; soft stillness and the night
> Become the touches of sweet harmony.
> Sit, Jessica. Look how the floor of heaven
> Is thick inlaid with patines of bright gold;
> There's not the smallest orb that thou behold'st
> But in his motion like an angel sings,
> Still quiring to young-eye'd cherubims;
> Such harmony is in immortal souls;
> But, whilst this muddy vesture of decay
> Doth grossly close it in, we cannot hear it.

We can comprehend the cosmos in some measure, Pythagoras thought, because there is a harmony in our souls that corresponds

to its harmony – which is mathematical. In his dialogue *Timaeus*, Plato was to elaborate this idea into a complete parallelism between the cosmos, or macrocosm, and the human being, or microcosm. Most modern scientists have little time for that Platonic dialogue: Sir James Jeans dismissed it as "the weakest of them all" and criticized especially the alleged correspondence. An exception was Werner Heisenberg, one of the founders of quantum mechanics, who has testified that the *Timaeus* was influential on his early thinking. But the *Timaeus* is the earliest complete Western work on cosmology to have survived and deserves some consideration. In that dialogue Plato gave us another reason for believing that we can begin to understand the cosmos: it is the creation of a mind immensely greater than our own minds, but of the same general character. In Plato's time, and until quite recently, the word cosmology had much wider connotations than it is often given now. The subject matter signified by the word was considered more a part of philosophy than of science. Indeed, in a 1950s undergraduate astronomy course I was taught to make a distinction between cosmology (a part of philosophy) and cosmogony (a part of science), but the latter word is rarely heard now and if used at all usually refers to study of the origin of the solar system. Modern, purely scientific cosmology could not begin until we had the theoretical background of Einstein's general theory of relativity and the observational background of Hubble's discovery that other galaxies appear to recede from us with velocities proportional to their distances. Perhaps because this latter discovery was quickly followed by the Depression and the Second World War, modern scientific cosmology did not really gain momentum until the late 1950s or early 1960s. Scientific cosmology as we now know it is certainly a major part of the human effort to comprehend the cosmos but if the cosmos is more than the physical universe that we observe, then cosmology must be more than the scientific part of the subject.

The eighteenth century, the century of Enlightenment and the one that followed the publication of Newton's *Principia*, saw a great flowering of both music and mathematics – the two Pythagorean themes again. Newton had destroyed for ever the possibility of literal belief in the music of the spheres but

paradoxically his work seemed to release a great creative urge to reproduce that music. Beautiful music poured out of Mozart, for example, apparently effortlessly and, at much the same time, beautiful mathematics poured out of Leonhard Euler, also apparently effortlessly. Did they both come from the same source? Is mathematics a human invention or is it built into the very fabric of the cosmos? Do we discover mathematical theorems or create them? You will find mathematicians on each side of that argument and I will return to the matter. Scientists tend to forget that the same ambiguity exists in the field of artistic "creation". Michelangelo appears to have believed that a sculptor's job was not so much to create a statue as to reveal what is already present in the block of stone. I once heard the Canadian philosopher of aesthetics, Francis Sparshott, remark that if Michelangelo was right he was very fortunate that he always got blocks of stone containing his kind of statue, while Henry Moore received only blocks containing his kind! Of course Michelangelo could not have meant what he said literally, but other creative artists – including, I believe, Mozart – have similarly felt that their "creations" were in some sense given to them; and it seems to me that any philosophy of aesthetics must take seriously what the greatest creative artists have said about their own roles. Have Michelangelo's "David" and Mozart's "Exultate Jubilato" existed from all eternity only to be discovered by those we call their creators?

But if what we usually think of as artistic "creations" are really discoveries, are what we call scientific "discoveries" really creations? Did Einstein create the theory of relativity or Darwin that of evolution? Eddington, half-seriously, did argue that Rutherford had "manufactured" the atomic nucleus rather than "discovered" it! As far as I understand them, post-modernists regard scientists as creators. Thomas Kuhn's reading of the history of science as the replacing of one paradigm for "normal science" by another gave some support to the idea. But although this way of thought is called "post-modern", it is actually quite old. Much of Poincaré's book from which I quoted earlier is taken up with a critique of such ideas, there called "nominalism"; even Galileo's remark about the language of the book of Nature is aimed at

something similar. It has been argued that Newton's laws of gravity and motion might have been expected to emerge from a newly restored monarchy; and that no-one should be surprised that the "principle of uncertainty" was "discovered" between the two world wars in the Weimar republic. Yet space probes launched in the twentieth century, in accordance with Newton's laws, by both capitalist and communist societies, barring accidents, do reach their marks; and dictators who could make trains run on time still had difficulty with the positions and motions of electrons!

Of course scientists are children of the society and the age in which they live and this must affect both their choice of and approach to, the problems they tackle. Most of them however are, I believe, realists at heart (although realism is much harder to maintain in the subatomic realm, which we cannot experience directly) and they react rather strongly against suggestions that their work is determined by social conventions. Let us return to the question of mathematical truth. Consider the famous equation $e^{i\pi} = -1$ usually ascribed to Euler who discovered (or created) it in his early twenties. It is difficult to explain this equation in a short time to non-mathematicians, but everyone who has studied mathematics far enough to encounter it has been struck by its beauty. Mathematicians call e and π transcendental numbers and i (the square-root of -1) an imaginary number. There is nothing in the definitions of these numbers to lead you to expect so simple a relationship between them. Two of the numbers at least, e and i, appear to be quite artificial, yet all three of them recur time and again in formulae that describe the behaviour of the natural world. I find it hard to believe that this equation is not the expression of something eternally true about Nature – that $e^{i\pi}$ could have had some other value if Euler had lived at a different time in a different society. There is even a story that Euler used this equation to "prove" the existence of God in a public debate with Diderot at the court of Catherine the Great. If he did, he presumably regarded it as a special case of the argument from design and he too must have seen the formula as the expression of an eternal truth.

On the other hand, if Leibniz rather than Newton had been the first to show that the inverse-square law of gravity can explain both the fall of an apple and the motion of the moon around the

earth, Leibniz's ideas of monads and pre-established harmony might have led to a very different philosophy from that of the mechanistic universe that eventually emerged from Newton's thought – with incalculable consequences for the subsequent development of science and its relationship with other aspects of our culture. Coming after both Newton and Leibniz, Kant reminded us that we impose our own categories on Nature, who sometimes refuses to fit into our pigeon-holes. Neither matter nor light can be forced into our mutually exclusive categories of "wave" and "particle", which perhaps provides some grist for the post-modernist mill.

There is ambiguity, then, about the status of both artistic "creations" and scientific "discoveries". If one is telling us about the real world so, in some way I believe, is the other. The difference seems to me to be that in science specific discoveries would sooner or later have been made even if the people who historically did make them had not lived, but the broad scientific view might well, then, have developed differently. In the arts, on the other hand, we would not have specific works of art if their creators had not lived but certain broad trends would still exist. Without Beethoven, we would not have the "Eroica" or the late string quartets, but someone would have initiated the transition from classical to romantic music which was necessitated by the internal development of the arts, the *Zeitgeist*, or perhaps, after all, Schubert's *Lieder* waiting from all eternity to be discovered! Perhaps J. B. S. Haldane thought of art and science as complementary when he wrote over seventy years ago (emphasis added again):

> Our only hope of understanding the universe is to look at it from as many different points of view as possible. This is one of the reasons why the data of mystical consciousness can usefully supplement those of the mind in its normal state. *Now my own suspicion is that the universe is not only queerer than we suppose, but queerer than we* can *suppose*. I have heard and read many attempts at a systematic account, from materialism and theosophy to the Christian system and that of Kant, and I have always thought that they were much too simple. I suspect that there are more things in heaven and earth than are

> dreamed of, or can be dreamed of, in any philosophy. That is the reason why I have no philosophy myself, and must be my excuse for dreaming.

Haldane sounds less confident than Poincaré, but I believe the differences between them are more apparent than real. Perhaps Einstein held the balance between them when he wrote (my emphasis again):

> The very fact that the totality of our sense experiences is such that by means of thinking ... it can be put in order, this fact is one that leaves us in awe, but which we shall never understand. One may say "*the eternal mystery of the universe is its comprehensibility*". It is one of the greatest realizations of Immanuel Kant that the setting up of a real external world would be senseless without this comprehensibility.
>
> In speaking here concerning "comprehensibility", the expression is used in its most modest sense. It implies: the production of some sort of order among sense impressions, this order being produced by the creation of general concepts, relations between these concepts and by relations between the concepts and sense experience, these relations being determined in any possible manner. It is in this sense that the world of our sense experience is comprehensible. *The fact that it is comprehensible is a miracle.*

Einstein defines very clearly the modest sense in which he believes the world of our sense experience to be comprehensible: it is the production of order (the root meaning of cosmos) from our sense experiences by means of general concepts and (primarily mathematical) relations. The harmony and beauty that Poincaré saw have appeared again. Nowhere did Poincaré, Haldane or Einstein claim that the world of our sense impressions is all there is, or that our understanding of it can be complete. But we are capable of a modest degree of comprehension and that is a miracle and a mystery – unless we agree with Plato that the cosmos is the creation of a mind not unlike our own.

Alan has not left me much debating room. His answer to the question "Can we comprehend the cosmos?" is "We are capable of a modest degree of comprehension and that is a miracle and a mystery". That seems not too far from my position that "we cannot comprehend the cosmos conceptually". However, I think there are some significant differences that can be fruitfully explored. One is the first "theme", as Alan calls it, that he finds in the quotation from Poincaré. Namely, "that a real cosmos exists 'out there', independently of ourselves". I want to focus on the words "out there" and "independently". They evoke the idea that we humans are able to separate ourselves as subjects or independent observers from the cosmos which exists "out there". Then as scientists we are able to observe, examine and conduct experiments on Nature (the cosmos) and thereby obtain independent, objective knowledge. Indeed this was a popular paradigm in both science and social science which led us to think that we humans could indeed comprehend the cosmos.

In recent years this idea that the cosmos exists out there *independently* of us as knowing subjects has rightly come under heavy attack. First because it is simply not true! We humans are not separate from the cosmos but are fully integral parts of it. It is not "out there", rather we are "in it". And this makes a huge difference to the way we know it. We do not know it as an object existing independently of ourselves – a mistaken approach which has led us to exploit nature ruthlessly as if what we did to it would not affect us (land us in our current environmental crisis). Instead, as we now realize, we can only know the cosmos from "within" – knowing ourselves to be not *independent observers* but *interdependent parts* of the whole. We are in nature; it is not separate from us. This is an immense shift in approach – one which is embodied in several contemporary critiques of the old paradigm of "objective knowledge", namely, postmodernism, feminism and ecology. Each of these critiques in its own way demonstrates that we humans are not separate from the cosmos and, to the degree that we can know it, we know it from within, not from without. There is no epistemological helicopter or spaceship that can lift us

up over the cosmos so as to see it as existing out there, independently from us. All of this has important ethical implications for the way we know ourselves in relation to nature and to each other – many of the research projects of our Centre for Studies in Religion and Society (e.g. "Population, Consumption, and Ecology", "Cross-Cultural Health Care Ethics", and "Ethics and the Canadian Fisheries") are research explorations within this new way of knowing. But let's come back to our key question, "Can we comprehend the cosmos?" If we can't do it with the old idea of separate, objective knowledge, can we do it using this new approach – knowing by being part of the whole – "ecological knowledge"? If we correctly see ourselves as but a tiny interdependent part of the universe, how much knowledge will this allow us to gain of the cosmos?

The Limitations of Ecological Knowing of the Cosmos

First, we must give up our human pretension that full knowledge of the cosmos is just around the corner. As soon as we accept that we cannot know the cosmos as "out there" existing independently, it means that our knowledge must necessarily be realized from "within" as a part of the cosmos – and a mighty small part, at that. Here the classical Chinese landscape painters, Bach and the astronomers seem to agree. In the grand scheme of things, we humans are but tiny dots in the vastness and majesty of the universe. As such the knowledge we can achieve of the whole is necessarily limited by our smallness – psychologically, philosophically and theologically. Psychologically we are limited in that our sense organs sieve out only a small sample of the universe in which we live. And while our minds are marvellous, they are small and limited in their ability to comprehend the complexity of the world which we only partially perceive – let alone the whole of the cosmos. The philosopher Immanuel Kant showed us that philosophically we are also limited in that we can never achieve knowledge of the *Ding-an-sich* – the object-in-itself. Similarly, in Western religion, we find that when Job tries to understand the evil that is unjustly visited upon him, he is convinced in his dialogue with God that he is not capable of thinking God's thoughts and knowing the universe as God knows

it – Job can only trust God. Add to Job's experience of his smallness before God and the universe the fact that both Judaism and Christianity see humans as flawed by sin and selfishness, and little doubt is left about our limitations. (Richard Dawkins, the Oxford zoologist, maintains that our genes are innately selfish.) The evidence before us, from psychology, philosophy and theology is that our limitations as human beings prevent us from comprehending the cosmos.

But can we not have at least partial knowledge? That indeed is Alan's claim, and one with which I do not disagree. The debate between us may well be over the *kind* and the *degree* of partial knowledge of the cosmos that we as humans can achieve. Let us examine this question from the perspectives of both religion and science. Western religion (Judaism, Christianity and Islam) seeks to overcome the limitations of our human natures by revelation – God, who as creator of the cosmos is all knowing, graciously gives to us, through scriptural revelation, the knowledge we need to be able to live life as God would have us live. Through this revelation we are given inspiring glimpses of God's knowledge of the cosmos, but never full knowledge. Only God, who does not have our sensory, mental and sinful limitations, has full knowledge.

But what about scientific or rational knowledge? How much can we overcome our epistemological limitations through the rigorous application of reason and of scientific method? Alan, following scientists such as Poincaré, Haldane and Einstein, suggests that we are capable of a modest degree of comprehension of the cosmos – but not complete knowledge. With this claim I agree. Einstein held the universe to be modestly comprehensible from our sense experiences by means of general concepts and relations (primarily mathematical). It is through our knowledge of "general concepts and relations", as Einstein puts it, that philosophy and science have hoped to transcend our human limitations. To what degree is this possible? To a "modest comprehension of the cosmos" claims Einstein and with this Alan, in his conclusion, seems to agree. But earlier on in his statement Alan seemed to want to make less modest claims about the possibility of mathematics to express the eternal beauty, harmony and order of nature – remember his discussion of Euler's formula $e^{i\pi} = -1$. This suggestion, by Alan,

tempting though it is, raises two questions: first, do such mathematical discoveries reveal knowledge of the cosmos that transcends our biological and social limitations? Second, can such mathematical statements capture and incorporate our limitations *and our necessary interdependence* as tiny humans within the ecological whole of the cosmos? I am not enough of a mathematician to know the answers to these questions, but I am sceptical.

The Buddhist Critique and the Possibility of "Tacit Knowledge"

We have agreed that in spite of our very real psychological, philosophical and theological limitations, we may through religious revelation, reason and science (especially mathematics) arrive at a modest comprehension of the cosmos. But even this conclusion is doubtful to a Madhyamika Buddhist (i.e. a follower of the third century AD Buddhist philosopher Nagarjuna). In the Buddha's analysis of our everyday experience of the cosmos he found that the thing that prevents us from experiencing its innate beauty, harmony and compassion is the selfishness generated by our false sense of ego or "I-ness". Rather than seeing ourselves as an interdependent part of the universe (as we really are), we typically think of ourselves as an "I" or "me" that exists separate from the world. This causes us to be selfish in our thought and action – to look out for "number one" as popular wisdom puts it. And so we strive for material possessions and sensuous pleasures for ourselves only to find that we always want more, and what is worse, that we become ego-attached to the things we have. When something happens to them, we lose them, they deteriorate or we lose someone we love, then we are left in a state of dissatisfaction and frustration – the beauty of the sunny day turns black for us, even though the sun is still shining and the beautiful rose smells sweet to others. To free ourselves from this blackness, this frustration with life, said the Buddha, we have but to give up the fiction that we are an ego or I-self that exists separate from other humans, animals, plants, etc. There is no "I" in the universe – only the whole cosmos of which you are an interdependent part. Buddha's sixth-century BC enlightenment is very like our

ecological vision of today.

But what does all of this have to do with our question, "Can we comprehend the cosmos?" Nagarjuna, a third century AD Buddhist scholar applied the Buddha's teaching to our ability to know the cosmos – and finds that we are severely limited in two ways. First, our language is very limited in what it is able to capture and convey through words and sentences. At the level of practical everyday affairs – buying groceries, calling a plumber or planning and building a house, it works reasonably well. But when it comes to saying what is true or real or even expressing what love is – on this higher level language is simply not capable of expressing our experience. Even if we do have a wonderful moment of love or an inspiring glimpse of the harmony of the cosmos, when we try to press these insights out into words and sentences, language – whether it be the language of rational science, philosophy or theology – fails. Even Shakespeare's sonnet on love does not capture love in a definition but only uses words poetically to evoke what cannot be said explicitly. But this is only half of our limitation. Our second and equally serious problem is that just as we become ego-attached to our possessions (our house, car, office, husband, wife, lover, child) so also, in our ignorance, we become ego-attached to our words – our articles, books and lectures in which we put forth our comprehension of reality ... of the cosmos. After having "sweated blood" through hours, days and years of dedicated work in our lab or study, we present to the world our hard-won understanding of truth and reality. And even though we are aware of the limitations of our senses, our small minds and our language, we all become ego-attached to our production: our comprehension of the cosmos as blessed by the imprimatur of Oxford, Cambridge or Chicago University Press, *Nature* or the *Scientific American*. We love it, it is our thesis and naturally we defend it and debate it against other viewpoints. Before we know it, we are implicitly claiming ultimate truth for our science, our philosophy, our politics, our theology. Not only do we try to beat the other person or competing position into submission with our take on the universe, but too often these debates translate themselves into political or religious wars – or equally violent intellectual inquisitions of various forms. The Buddhist critique

makes it abundantly clear that we cannot comprehend the cosmos through language, and that failure to recognize our limitations in this regard has resulted not only in ignorance, but also in the warfare and suffering that fills much of human history.

But Buddhism does not stop here, for Buddha did not claim to be leading his followers into darkness or nihilism, but *Nirvana* (seeing the cosmos after the flame of desire or ego-attachment has been blown out)! Once we give up our ego-attachment to our science, philosophy, theology, etc. (through meditation and right living) we will no longer make the mistake of claiming even implicitly ultimate truth for our words and ideas. Respecting the limitations of our senses, minds and language, we will not claim more than a practical value for our conceptual knowledge. And having gotten over thinking of ourselves as an "I", "Me" or "Self" which exists separate from everything else – means that we are now freed from our selfish desires to see clearly the cosmos as a beautiful, harmonious whole, of which we are but a tiny interdependent part. Buddhist *Nirvana*, it turns out, has much in common with our contemporary ecological approaches, but with some definite differences. Buddhism teaches that while we can never comprehend the cosmos through thought and language we can know it directly by meditation. By disciplined forms of spiritual practice (e.g. Zen meditation) one can remove the fiction of "ego" or "I-ness" and its attendant desiring – including attachment to theory construction – and then what remains will be a transparent perception of the cosmos as an ecological whole. Thus, for the enlightened Buddhist, the cosmos cannot be known through language but its beauty, harmony and compassion can be directly realized. This, of course, is what we call "mysticism". Mysticism is also the place where leading cosmologists of our day (Paul Davies, for example) end up in attempting to answer the question, "Is the cosmos comprehensible?" Davies in his book, *The Mind of God*, concludes that complete scientific knowledge of the cosmos is doomed to failure. There is a sense of order emerging from chaos which we can to some extent understand through mathematics but we quickly bump up against the limits of scientific knowledge pointing us to a deeper mystery. In his presentation, Alan, too, concluded that we end in mystery.

Being pointed toward a mystical understanding of the cosmos may be the common result of our dialogue but is it the same thing for Alan or Paul Davies as it is for the enlightened Buddhist? For us ordinary people (non-mystics – who have not spent years as a Benedictine, a Sufi, a Yogi or a Zen master), the very word "mysticism" is a very unfortunate one. It suggests mist and therefore foggy, confused or vague thinking. For the philosopher Bertrand Russell, mysticism signals only an emotion and therefore is simply subjective. But when an examination is made of the experiences reported by the great mystics of all traditions, something quite different emerges. Rather than being "misty" or "confused", mystical experiences are typically described as clear illuminations, having all the qualities of direct sensory perception – only more vivid and real! We have all had such experiences: finding ourselves transfixed by a morning sunrise as we stepped out our back door, feeling our tinyness in the vastness of the star-filled night sky or looking out from the top of a high mountain, losing oneself in the orderly harmony and majesty of a Bach fugue, or being caught up into the expanding joy of love with one's beloved. All these are mystical experiences. The difference between us and a mystic is that for us they are the unusual whereas for the mystic they are the usual. As one Zen master put it, "What is normal for you is abnormal for me; what is normal for me (the mystical) is abnormal for you." The testimony of the mystics (and probably of each of us in our moments of spontaneous illumination) is that that is the real, the truth of the cosmos. When we analyse those moments, we find that we were taken up out of our narrow ego-selves into the experience of ourselves as part of a larger whole. For me such moments do not run counter to my work as a scholar. Rather they give me a larger frame of reference within which to place my scholarship: detach it from my ego and its biasing desires, and enable its results – limited though they be by finiteness and language – to approximate ever closer to the cosmos. And the closer I draw through science, philosophy, theology and the compassionate living of daily life, the more tuned I am to the evocation of the mystical in everything. The two are complementary.

Can we comprehend the cosmos? Only by letting go of our sense

of ego separateness (I am here and it is an object "out there" for me to study and understand). By coming to see ourselves as but a tiny interdependent part of the whole (like the Chinese landscape) with a very limited ability for conceptual understanding, and by practising the spiritual disciplines of the mystics, we can come to know the cosmos.

Response by Alan Batten

I have two comments on Harold's discussion that I believe are related to each other and which I shall try to present as briefly as possible. First, the question of the subject-object distinction which he criticized. I chose those words because I wanted to emphasize the philosophical realism that I believe is part of the scientific attitude, but scientists themselves, by using the subject-object distinction, have discovered its limitations. As long as we were concerned with (mainly inanimate) objects in the middle range of size (anything from a speck of dust to a cluster of galaxies!) scientific objectivity worked, but as soon as we began to consider atoms or sub-atomic particles, we found that observation itself could in some way affect those particles. Similarly, when we consider the whole universe, as Harold pointed out, we cannot escape the fact that we are part of it. This seems to me to be the real lesson of the so-called "anthropic principle", which in its original form asserted that "what we can expect to observe must be restricted by the conditions necessary for our presence as observers" (Carter 1974). Of course, Poincaré himself could not know of these modern developments. *La Valeur de la Science* was published in the same year that Einstein published the special theory of relativity and what is now recognized as one of the seminal papers in quantum theory. General relativity was not published until 1916, four years after Poincaré's death.

My second comment arises from the inconsistency that Harold has pointed out between my relatively modest conclusion that we are able partially to comprehend the cosmos and my remarks on mathematical truth, in particular about the equation $e^{i\pi} = -1$. I admit the inconsistency, which arises from my own uncertainty about the status of mathematical truth, an uncertainty that has not been fully resolved either by mathematicians themselves or by philosophers of mathematics. In the early decades of this century, there was a very lively debate on the nature of mathematics, in which Poincaré was an active participant, as were also Bertrand Russell and A. N. Whitehead, who published their three-volume *Principia Mathematica* between 1910 and 1913. It would take too long to try to describe this debate in any detail; it is still not

completely resolved, although it was changed by the publication of Gödel's incompleteness theorem in 1931. According to this theorem, in any axiomatic system there exist propositions whose truth cannot be demonstrated within the system. The proof is to show that the theorem itself is just such a statement: paradoxically, we know it is true because we cannot prove it! Gödel himself took a very Platonic view of mathematics; he saw mathematical truths and entities as eternally existing and discovered, rather than created, by human mathematicians. Many mathematicians take this view and I think I made clear that I am attracted to it, although I have little claim to call myself a mathematician and none at all to call myself a philosopher of mathematics. On the other hand, the nineteenth-century German mathematician, Leopold Kronecker, once exclaimed "God made the whole numbers; all the rest is the work of man!" Others have even questioned the status of the natural numbers. I disagree with Kronecker: I believe that God made π – and I strongly suspect that He was implicated in the manufacture of e and i ! It is not surprising that some mathematicians should take this Platonic view, Plato himself was an expert geometer and his theory of ideas or forms arose out of his knowledge of geometry. Vulnerable to criticism though it may be, that theory is at its most plausible in a geometrical context. Perhaps Plato's understanding of mathematics forced him to take the first steps that were to distinguish Western rationalism from Eastern mysticism and which led to the subject-object distinction that has characterized Western philosophy, theology and, until this century, science. Despite Harold's persuasiveness, I am not yet convinced that these were false steps. The Buddha, I fear, was not a mathematician! It may be that your attitude to the status of mathematical truths will be the touchstone of whether you agree more with Harold or with me. If mathematics is a human invention, then our mathematical understanding of nature is of no great significance; but if mathematics is something eternally true, whether or not human beings exist, then our physical science is indeed the beginning of a true comprehension of the cosmos.