On a Christian Cosmogony

or: Why not take Genesis 1 as history and try to put together a cosmogony that fits it?

This is an elegantly posed question which is instructive and informative to answer as it stands.

Genesis 1 is not history, cannot be history, and was not intended to be history. Cosmogony ("a theory, system, or account of the creation or generation of the universe" OED,2b) could never be properly historical, and currently we cannot conceive of it as being properly scientific. Cosmogeny ("evolution of the universe", OED) is properly scientific, but is not directly treated in the first Genesis creation account. And even if it were, the proper way to do science is to start with the evidence and to proceed to the conclusion. The suggestion that one should determine a conclusion arbitrarily from a text and then fit the evidence to suit is a shocking distortion of the the proper way to search for truth and should be abhorred by all Christians.

Let me unpack this answer so that you can see what I do (and every Christian ought to) believe, and also what I do not (and no Christian should) believe.

On Genesis

History

The first part of the question asserts that the Bible in general and Genesis 1 in particular is historical. This assertion is a very attractive one. In particular, there is absolutely no doubt that Christianity is nothing if not a historical religion. This is made crystal clear in a variety of places. Dr. Luke is explicit about drawing up *an account of the things that have been fulfilled among us, just as they were handed down to us by those who from the first were eyewitnesses* (Lk.1:1). Peter was equally explicit: he told the people at Pentecost, *God has raised this Jesus to life, and we are all witnesses of the fact* (Acts 2:32). Paul was no less definite: *What I received I passed on to you as of first importance, ... [Christ] was raised on the third day ... and appeared to Peter, then to the Twelve ... [then] to more than 500 of the brothers at the same time, most of whom are still living ...* (1Cor.15:3ff). John warns us to remember that only a partial record of events is available (John 20:30), but to neither add to nor subtract from the record we have (Rev.22:18-19, and see also Deut.4:2). The concern to emphasise historicity is more veiled in the Old Testament, but is strong nevertheless, and occasionally quite explicit, as when the Psalmist says, *To this I will appeal, the years of the right hand of the Most High: I will remember the deeds of the LORD* (Ps.77:10f).

How do we know that these things are so? It is because we have reliable records of reliable eyewitnesses. There is nothing metaphysical about it, here we are in the realm of (to me very comfortable) evidence of the usual kind.

I want to emphasise this point, if only because Lord Durham's book "The Resurrection of the Son of God" (N.T.Wright, 2003) is so recent. It seems to me that it is this book which has securely established the central Christian claim, that of the historicity of the Resurrection, against the critical assaults of eight generations of theologians, and against atheist scepticism. Durham does not change any orthodox understanding of Scripture, in this sense his book has no surprises for us. What it does do is answer in enormous detail all the various questions that have arisen in modern times over the text, in the process sharply illuminating our understanding of what the original text actually means.

I also want to emphasise the point because it seems to me that it is of great importance to insist that we are *sensible* when discussing the Scriptures. Sensible: that is, willing to use our senses. Remember David's injunction, *Taste and see that the LORD is good!* (Ps.34:8). Remember John's

cool recollection: *That ... which we have heard, which we have seen with our eyes, which we have looked at and our hands have handled, proclaim we concerning the word of life. ... we have seen it and testify to it ...* (1John 1:1). Jesus himself, as carefully recorded by Dr. Luke, encouraged the disciples with, *Touch me and see - a ghost does not have flesh and bones as you see I have* (Lk.24:39).

The question "how do I know what I know" is a good one, and is one that apparently God *expects* us to ask, given all the various Scriptures cited above. And these are only a small selection of the Scriptures we could have considered. Modern commentators often draw a distinction between science and religion, between "facts" and "faith", as though the one was purely speculative and the other firmly established. In fact, life is not like that: not only is the scientific community susceptible to fashion, error, and other vagaries of the human condition, but the Christian community starts from an assumption that the believer requires a firm foundation for his belief. On the other hand, the philosophers have made it plain with considerable detail that the scientific enterprise is itself firmly based in the human desire for meaning; all science is based on faith, at minimum the faith that the world is comprehensible in principle, and that we can ourselves comprehend it in practice.

The Genesis Creation Accounts as Revelation

So when I say that Gen.1 is not history, it is not because I do not expect the Bible to be historical: quite the contrary! The Bible is deeply historical in its very essence, but not all of its books are historical books. Lord Durham has listed five different meanings of "historical" in his book (op.cit.) in a very acute discussion of what can be expected from a historical treatise such as his. Summarising, we have (firstly) history as event, then (secondly) history as significant event, then (thirdly) history as provable event, then (fourthly) history as writing-about-events-in-the past, and (lastly) history as what modern historians can say about a topic. Durham comments acidly:

> Confusion between these senses has of course bedevilled this very debate about the so-called 'historical Jesus', the phrase being used by some to mean Jesus as he actually was (sense 1), by others to mean what was significant about Jesus (sense 2), by others to mean that which we can prove about Jesus, as opposed to that which we must either doubt or take on faith alone (sense 3); by others again to mean what people have written about Jesus (sense 4). Those who ... have taken the phrase in sense 5 have often rejected the Jesus not only of that sense but, apparently, of the previous four as well.

In what sense can the first Creation account be "historical"? It appears that several of the senses above might apply, until we ask the question, "how do you know?". How can one write "history" about a time when there were no men to be eyewitnesses, which is *always* the Biblical sense? If there are no eyewitnesses it cannot be history, but must instead be revelation. Is the author of Genesis (probably Moses) aware of my distinction here between history and revelation? It seems to me that not only is he very aware, he takes every pain to emphasise this very distinction.

Consider the phrase "it was so", used six times in this Account (vv. 7,9,11,15,24,30). This phrase is never used again in the Torah, and is only used one more time in the Hebrew Old Testament (2Kings 15:12), at the place where the LORD speaks to Jehu that his sons would be on the throne until the fourth generation: it is a word of revelation. Interestingly, the LXX (the *Septuagint*, the Greek translation of the OT prepared in Alexandria in about 200BC) uses the Greek phrase "*kai egeneto outos*" in rather more contexts. They use it seven times in the first Genesis account, adding the phrase to v.20 (as well as switching it from v.7 to v.6). It is also used at Judges 6:38 (where Gideon wrings out the fleece), 1Kings 17:22 (where the life comes back to the boy), and 2Kings 7:20 (commenting that Jehoram's captain died in the gate according to the word of the LORD spoken to Elisha). The LXX may reflect a more reliable text (since their Hebrew MSS were some 1000 years earlier than those that the Masoretes used), but usually it reflects an interpretation of the Alexandrian scholars. Note that the Christians used the LXX almost exclusively for the first

400 years (until Jerome translated the Vulgate from the Hebrew) (except for the Syriac and Hebrew churches of course) so that it is always interesting to look at the LXX version.

This phrase "it was so" is a clear signal that it is God's finger at work, and that the confirmation of real events follows the prophetic word. How do you know God speaks truth? Because it has come to pass, just as he said it would. The important passage at Deut.18:21f (alluded to in John 5:46) underlines this. The language, and the language usage, sets the Creation Accounts apart from the rest of the book of Genesis. Many scholars see this and conclude that the book of Genesis is a hotch-potch of various sources all slung together to make a poorly edited book of disparate parts. I take an entirely opposite view. It seems to me that Moses did not have clearly in his mind the modern genres of "history", "law", "myth", "poetry" etc. How could he have done? There was not even any comparable literature at that time (~1600BC). As a literary work, the Torah is unprecedented in its style, its scope, its coherence, and the sheer quality of the writing. The text bears inspection. Indeed, the text has borne the most intense inspection over three millenia of the acutest minds. Moses switches at will from prophetic revelation to high poetry to beautiful narrative to cold law to careful description, and all with the overriding purpose in mind to *communicate truth*.

The Restraint of the Text

I have considered the phrase "it was so" in some detail, but I could treat the words "firmament" or "creation" in the same way and come to the same conclusions. Doubtless there are many other features of the text that also flag its exceptional status. But let us move on. Let me press the idea of historicity implying eyewitnesses a little further. Consider the wonderful passage at Joshua 10 where the sun stands still. Clearly, we cannot today conceive of any way in which the sun can actually stand still, relative to the earth. But it is important to realise that the Chronicler could not either, although his understanding of the physics was not as well informed as ours is. Recall David's exclamation "the heavens declare the glory of God" (Ps.19) and that the heavens were everywhere understood as the keepers of divine time, as Moses also makes clear at Gen.1:14. Recall too that God's word is reliable and irrevocable: reliable since God always stands by his word, notice Gen.22:16 and the gloss on this of the writer to the Hebrews (6:13: interestingly, he quotes v.17); and irrevocable since there is no greater than God to oppose his word (see 2Sam.23:5, "yet hath he made with me an everlasting covenant, ordered in all things, and sure"; see also Esther 1:19; 8:8; Dan.6:8,12,15; Job 41:10). So how does the Chronicler treat this unbelievable story? *He cites his source!* "Is not **this** [emphatic pronoun] written in the book of Jasher ['the Upright']?" he says (v13).

The biblical text is astonishingly restrained, not only by the standards of the time but by our standards too. Just compare with any of the Apocryphal books (comparable ancient writings, interesting in their own right) and you can see the difference in tone. So in "Daniel, Bel and the Snake" the story of Daniel in the lion's den is expanded upon, and the prophet Habakkuk is sent to take food to Daniel in the pit. He takes him "by the crown of his head, and carrying him by his hair, he swept him to Babylon with the blast of his breath". What does this add to the story, except incredulity? Note that in the comparable passage in Acts (Acts 8:39) the text does not multiply incredulity by adding detail. Even in the story of Daniel and Susanna, which I like, Daniel addresses the two lecherous elders with contempt, "you hardened sinner" and "you spawn of satan": completely differently from the way Jeremiah addresses Hananiah, not only with respect but letting him have the last word (Jer.28:11). Except of course that the word of the LORD comes subsequently to Jeremiah for Hananiah, and he dies as prophesied (Jer.28:17). Jeremiah speaks hard words to Hananiah, but he does not abuse him.

In the popular imagination the Biblical text is taken as the incredible work of primitive people, unreliable through and through. In fact, close attention brings us to a conclusion that could not be

more different. The text itself is astonishingly uniform, especially considering its age and the vicissitudes it has suffered. We can *prove* from the Dead Sea Scrolls that the Masoretic text of Isaiah of c1000AD is *identical* almost to every jot and tittle with the earlier text (~200BC). Everything we know points to the integrity of the text. And the quality of the writing is the more impressive the more it is scrutinised: the writers of these texts were certainly not intellectually primitive. I am used to reading accounts of things of which I have no personal experience, and I am used to asking the question, "how do they *know?*". When I read a scientific paper I follow in my mind the steps that are reported, and determine if I understand how to do the things described, and if I believe the reported results. There are many aspects to this sort of judgement, and I frequently reject papers I am asked to referee because I am not satisfied in this or that aspect. But rejection is quite hard work, since I must show *credible* reasons why I am right and they are wrong. Now, when I do the same thing with the Biblical text, I am looking for coherence, both an internal self-consistency and a consistency in the context of the external world; and I am looking for substance, what is the author saying and is it worth my attention? Even in the case of the sun standing still for Joshua, which is a glaring inconsistency with everything I know about the world, the text is restrained and credible, since it cites the actual text of the source, which is identified as one otherwise approved as reliable. So the Chronicler (who knows it is weird) carefully (and unusually) gives us all the data, weird and anomalous as it is, and lets us interpret as we wish.

A Christian Cosmogony: Time

A cosmogony ("the beginnings of the Cosmos") will always reflect the world view of the thinker. How the world began is a question that cannot be answered scientifically, and to think of it "historically" is absurd since there can in principle be no eyewitnesses. How did everything start, and why? These are philosophical (or, equivalently, religious) questions, to do with ontology: they are not scientific questions. They are *prior* to any scientific treatment.

So, the opening statement, "In the beginning, God created the heavens and the earth", is a very clear cosmogonical statement. One might think that the acceptance by modern physicists of the Big Bang, which also affirms a clear temporal start to our Universe, makes this aspect of it also a cosmogenical statement, but this is not the case since most of the exponents of the Big Bang theory also believe some sort of oscillating universe or multiverse conception which avoids this Biblical singularity. One should be clear that these alternate conceptions are speculative: they are unproved, and it seems plain that they are unprovable. One acute (and exceptionally well-informed) commentator believes that all times before the Planck time (10^{-43} seconds after the moment of creation) are essentially unknowable (Michael Rowan-Robinson, *The Nine Numbers of the Cosmos*, 1999).

Augustine as Christian Thinker

We believe that God created time, along with everything else. This of course sits very comfortably with modern physics, but it has been clearly believed by all Christians at least since the time of Augustine (~400AD). Note that this cosmogony cut across the informed opinion of the ancient world: Aristotle thought that it was absurd to think that the universe was not of infinite duration.

It is interesting to follow Augustine's line of thought. In the *Confessions* he gives an intricate discussion of the nature of time, that only the present really exists since the past is, well, past, and the future is yet to come. He asks, "What is time", and answers (XI:14):

> I know well enough, provided no-one asks me! ... If [the present] were always present and never moved on to become the past, it would not be time but eternity. If, therefore, the present is time only by reason of the fact that it moves on to become the past, how can we say that even the present *is*, when the reason that it *is* is that it is *not to be*?

In the course of a long discussion he explores a variety of interpretations of what precisely Moses meant. He says (XII:23):

> When a message is delivered to us in words, truthful though the messenger may be, two sorts of disagreement may arise. We may disagree either as to the truth of the message itself, or as to the messenger's meaning. It is one thing to enquire as to the true history of the Creation, another to ask what Moses, who was so good a servant to the family of your [God's] faithful, meant those who read or heard his words to understand by them. As for the first sort of disagreement, I wish to have no dealing with any who think things which in reality are false; and as for the second, I wish to have none with any who think that Moses wrote what was not true.

Just so! He discusses the differences between solar time and sidereal time, and indeed absolute time (XI:23). He notes that "day" can mean a variety of things, including the indeterminate time implied (to his mind) by Jos.10:12f, but that "day" as defined by the movement of the sun and "day" as being the time required for one rotation of the earth are logically distinct. Augustine is handicapped by his technology, which permits nothing but relative (and rather imprecise) time measures. He therefore seems to believe that time is in the mind: "Time is not the movement of a body" (XI:24); "I must not allow my mind to insist that time is something objective ... I say that I measure time in my mind" (XI:27). It is obviously this which is picked up by George Berkeley (*A Treatise Concerning the Principles of Human Knowledge*, 1710) when he asserts, "I am because I am perceived".

Augustine believes that "no moment of time passes except by your [God's] will" (XI:1). Time for Augustine is entirely God's creature: he created time when he created our universe: "there cannot possibly be time without creation ... before all time began you are the eternal Creator of all time" (XI:30). This is an astonishingly deep insight which was beyond the Greeks, for all their intellectual prowess. This is because it is a revealed truth, not one which can be deduced from observations of any kind. It is an essential part of a Christian cosmogony.

One might ask, why should one give any weight or consideration to Augustine's ideas? What relevance does he have for us? Why should we let him colour our attitude towards the sacred text? Was he not strongly influenced by pagan thought, and (possibly worse) by the Roman thought that nurtured the Roman church that the Reformers whom we revere fought so hard to save us from? And is not paying attention to the Fathers giving credence to Roman attitudes to Tradition which we deplore?

Well, I return again to the assertion that Christianity is a *historical* religion: history is essential to us. I also deprecate the corruption in the Roman church that made the rise of Luther, Tyndale, Calvin and the others such a blessing of God to the people of Europe, but one must always keep a sense of proportion. After all, it was this same "corrupted" Roman church that taught Luther, Tyndale and Calvin how to *think*. It was Luther and Tyndale who were the real catholics: it was the Roman church that expelled them, and the Roman church that proceeded to multiply its heresies (particularly at the Council of Trent).

What none of the Reformers did was to disturb in any way the doctrine of the Trinity, which has been current since the Cappadocian Settlement of the fourth century to which Augustine contributed so powerfully. The Nicene Creed, which encapsulates Christian Trinitarian doctrine, is accepted by all Christians, whether they call themselves Orthodox or Catholic, Protestant or Reformed or Fellowship. And Augustine's was a powerful voice advocating this Settlement. His book *De Trinitatis* (On the Trinity) is still impressive today.

I mention this because, for all his faults, Augustine was important in our history as a man who materially helped to clarify our understanding of who God is, who helped us to *speak correctly* (Job 42:7f) about God, who established that we can treat all of the Scriptures with equal respect since they are mutually coherent when speaking about God, and whose contribution remains valid

today. The Trinity is an issue of substantial importance in these days when the Islamic challenge is growing stronger: the first thing any Muslim will say to a Christian is that God does not have a son. You can read this at least three times in the Koran, but the most interesting from our point of view is the one that to my mind modifies one's understanding of all the rest: in Sura 6 ("Cattle") verse 101, it says, "How should [God] have a son when he had no consort?". Well, we too think it absurd (and blasphemous) to consider that God had a wife! But the fact that we can think coherently about God at all is due in large measure to Augustine.

We need to understand our history properly. Because understand it or not, our history will colour our attitude towards the sacred text: this is unavoidable. It comes back again to the questions, *how do we know what we know?* and *where do our ideas come from?*

A Scientific Cosmogeny

A cosmogeny ("the development of the Cosmos") on the other hand, although it is obviously not historical (no eyewitnesses!) can certainly now be approached scientifically with the new tools that have become available in the last 50 years or so. It is important to realise, however, that almost everything we know about the Universe outside our own Galaxy has been discovered since the First World War. So for most of human history, the difference between cosmogeny and cosmogony was only semantic.

As an aside, we have only been able to measure time absolutely in Augustine's sense for the last two hundred years or so (since Harrison won the Longitude Prize ~1765). But now, time is one of the creatures that we can measure at extraordinary precision (of attoseconds: 10^{-18} secs).

It was Newton's work on gravity, elaborated by the eighteenth century mathematicians, which finally allowed our detailed understanding of the movements of the sun and planets. The last anomaly in the observed positions of the planets was the precession of the perihelion of Mercury, which is an effect explained by Einstein's General Theory of Relativity. General Relativity was first confirmed by Eddington's observation of the gravitational lensing effect of the sun in a solar eclipse in 1919 (and many times since). This means that we now understand in detail how celestial objects move. Therefore our idea of "day" has also subtly changed. Previously the *sun* defined the day, now physics can determine the motion of the sun, hence *we* can define the day.

In the next part of the story we turn to the nuclear physicists. It became very clear in the 1950s that the origin of the chemical elements was in the nuclear furnaces of the stars. The question of what the sun actually is was already explored in the nineteenth century when Lord Kelvin (after whom the absolute scale of temperature is named) calculated that the sun would cool after only 10 million years. Obviously, Kelvin knew nothing of the transmutation of protons to helium in the sun, but it turns out that stars are fairly simple creatures which are now well understood, although many details remain to be clarified.

One benign consequence of the nuclear arms race is that a huge quantity of fundamental work in the nuclear sciences was commissioned in the post-War period, some of which went to supporting the massive body of work summarised in the seminal paper by Burbridge, Burbridge, Fowler & Hoyle (Rev.Mod.Phys., 1957: **29**, 548), who show how the genesis of all the elements (including those heavier than Fe, and including all the stable and radioactive isotopes, but not including helium) can be accomplished by well understood stellar nuclear processes, and moreover how the expected abundances of elements (except He) can be calculated, and how well the observed abundances conform to expectation. Hoyle hated the Big Bang hypothesis (his own term, intended derisively), and did his best until the end of his life to obtain experimental support for his preferred theory, the steady state hypothesis. However, it turns out that as time has gone on the steady state theory has become untenable experimentally. It is interesting that physicists have at last abandoned their preference for the eternal Universe, a preference which is inconsistent with Scripture. Of course,

this is accidental, and it is possible that fashions will change and some new observations will make a steady state theory tenable again. This will not make it true, and it will not make Scripture false. Only if we can *prove* that the Universe is eternal will we be forced to abandon our current understanding of Scripture. It seems to me that in this case it would be hard to remain a Christian: however, it also seems to me that it is extremely unlikely that the eternal Universe hypothesis will ever again become even *tenable*, let alone *provable*.

Not only were the nuclear physicists vigorously pursuing understanding of the evolution of stars of different masses, but from the other side the astronomers were making more and more detailed and extensive catalogues of the stars and their spectroscopic signatures. And intensive observations were being made in all wavelengths, infra-red, microwave, radio-wave as well as the visible. Also the cosmologists were making progressively more detailed calculations of the evolution of the Universe, given gravity and the known masses of stars. And of course, the basic observation that the sky is dark (Olbers' Paradox).

Hubble first published his claim of the proportionality of the redshift to distance in 1929. Stellar spectroscopy was already very far advanced, with the element Helium being discovered in 1868 by the independent observation of strong and unknown emission lines in the spectrum from the Sun by both Janssen and Lockyer. Elemental absorption and emission spectroscopy for the astronomers was an old and mature technology, which had recently made astonishing theoretical progress since with the quantum theory one could calculate the spectral lines of hydrogen, agreeing excellently with observation. The spectroscopists knew that well defined wavelengths (which they could measure with extraordinary precision) were characteristic of each element, and they now started to understand why. It was obvious that stellar motion could be characterised by a Doppler shift (proposed by Christian Doppler for binary stars in 1842 and observed by John Russell in 1844), and Hubble's claim started an enormous research programme that continues to this day.

It turns out that in 1929 Hubble seems to have been flying something of a kite, since it is not clear how he got the redshift from the limited observations he made on very local galaxies. For stars (and galaxies) close to us both red shifts and blue shifts are observed depending on the peculiar motion of the stellar object under observation. ("Peculiar" here is used in John Wesley's sense of particular, or special.) However, greatly extended observations show that Hubble's hunch was correct. The big problem in determining the value of the Hubble constant is in finding out the distance of the galaxy for which the redshift is known. The classical way to do this is by using the Cepheid Variable stars, whose luminosity is a known function of their period. As one looks further away these Cepheid Variables can no longer be resolved, and other methods must be used to determine distance. These are intricate procedures with many corrections to apply, and even today estimates of the Hubble constant vary by a factor of nearly two. But it is important to appreciate that the calculations themselves are very well defined: the reason for the uncertainty is that calculations on different sets of data which ought to give the same answer actually give different answers. This only means that we do not (yet) know enough to demonstrate a greater consistency between various datasets. And it is very clear that redshift increases with distance.

The simplest explanation of the Hubble constant is that the Cosmological Principle is valid. This is the principle that says that there is nothing special about our position in the Universe: there are no special positions. Then the existence of the Hubble constant means that the Universe is expanding, in the sense that every galaxy is moving away from every other galaxy (on average, ignoring the peculiar motions for now). After intensive studies there is every indication that the Cosmological Principle is valid, and no indication that it is not valid. Note that the universal opinion up to about 1950 was that the Universe was eternal, and some very eminent physicists maintained this opinion for many years. So this statement that the Cosmological Principle is valid is an *experimental* statement: no-one can find any valid interpretation of the data consistent with the failure of the Principle. And they have tried very hard.

Obviously, if the Universe is expanding then previously it was smaller, and gravitational theory shows that at some time it was vanishingly small (as shown by Stephen Hawking & Roger Penrose in a celebrated paper: *The Singularities of Gravitational Collapse and Cosmology*, 1970, Proceedings of the Royal Society, **A314**, 529-548). The question then is, when was this? What is the age of the Universe? It turns out that rather simple thermodynamic considerations (first sketched by Tolman in the 1930s) enable us to make some very general predictions; in particular that as we go forward in time from the moment of Creation, the temperature falls in inverse proportion to its size and the energy density of the Universe falls as the fourth power of the temperature, where temperature is measured from absolute zero on the Kelvin scale ("K" means "degrees Kelvin" where one degree Kelvin is the same size as one degree Celsius, and absolute zero is 0 K, or -273.15°C). At various temperatures various particles "freeze" out of the primeval "soup". Freezing is an example of a *phase change* and there are a number of these phase changes in this story.

At high temperatures, photons (mass-less particles of light which are always stable) can spontaneously generate particle-antiparticle pairs of massive particles according to the rules of quantum mechanics, and the $E=mc^2$ relation of special relativity. These sorts of reactions are well known and understood from particle accelerator experiments. The particles of interest to us here, apart from the photon, are the electron, the proton and the neutron. The neutron decays into the proton in the *beta-decay* process which involves an electron, and an anti-neutrino needed to satisfy the conservation rules.

At 1.09 secs after Creation the temperature is 10^{10} K and this is low enough for neutrinos to stop interacting significantly with the other particles: they have gone out of thermodynamic equilibrium. A black body energy distribution *for neutrinos* at 10^{10} K redshifted for the expansion of the Universe to today, should be observable. Unfortunately neutrinos barely interact at all with matter, so we currently have no way to test this prediction.

It is clear that there must have been a brief period of nucleosynthesis when protons "burned" to helium, and one can calculate what the ^{1}H/^{4}He ratio must have been at the end of this period. The coupled nucleosynthesis reactions which converted protons to helium (^{4}He nuclei) are:

$$p + n = {}^2H$$

$${}^2H + p + n = {}^3He + n = {}^4He$$

$${}^2H + p + n = {}^3H + p = {}^4He$$

where "p" means protons (^{1}H nuclei) and "n" means neutrons.

At 13.82 secs after the Creation the temperature is 3.10^9 K, and free thermal electron-positron pairs start annihilating on average: positrons are antimatter electrons and the PET (*positron emission tomography*) scans you might get today in hospital use this type of antimatter. Helium nuclei ($^4He^{++}$, otherwise known as *alpha particles*) also become stable. By the time the temperature has dropped to 10^9 K (182 secs after Creation) there are almost no positrons left, and ^{3}H (tritium) and ^{3}He nuclei have become stable.

Now ^{4}He is the most tightly bound nucleus; ^{3}He and ^{3}H (tritium) are more loosely bound and were only stable after about three minutes. But this set of nucleosynthesis reactions depends on the stability of the most loosely bound ^{2}H (deuterium) nucleus. This had to wait until 226 seconds after Creation (at 9.10^8 K). This is known as the "deuterium bottleneck". But as soon as deuterium was stable all the remaining neutrons in the Universe were more or less immediately "cooked" to ^{4}He, giving a ^{1}H/^{4}He ratio of about 3. There should also be some remaining deuterium, and UV measurements in 1973 of the interstellar gas absorption by deuterium by the satellite *Copernicus* showed that there is about 20 μg/g of the ^{2}H isotope of hydrogen, which implies 10^9 photons per proton in the Universe.

In the above account the numbers are very precise: they come from Steve Weinberg's 1977 marvellous book, *The First Three Minutes*). Now using standard spectroscopy techniques we can measure the current $^{1}H/^{4}He$ ratio (an essentially correct value of this ratio was given in 1956 by Suess & Urey), and because the stellar nuclear processes are now well understood we can also calculate how this ratio changes during stellar evolution. We can therefore make a very good *experimental* estimate of what the $^{1}H/^{4}He$ ratio was after nucleosynthesis stopped about four minutes after Creation, and *it matches the calculation!*

Nothing much happened after nucleosynthesis stopped, except that the expanding Universe got cooler. But photons and matter were still in thermal equilibrium since the Universe was still too hot for atoms to form: at this temperature all matter was in the plasma state, with photons and free electrons interacting readily. But after about 300 000 years the temperature had fallen to 3000 K, cool enough for protons and electrons to condense to neutral hydrogen atoms (helium atoms had condensed at much higher temperatures). This was another phase change (known as *recombination*), and as soon as it happened the photons stopped interacting with matter: the fog of the plasma cleared and the Universe became transparent. It was at this point that the Universe ceased to be in thermal equilibrium, and it is the final black body (equilibrium) temperature just before this phase change which (redshifted for the expansion of the Universe to today) should now be visible as ubiquitous radiation with a black body spectrum peaking at about 2 mm wavelength (equivalent to a temperature of 2.73 K).

Penzias & Wilson first published just such an observation in 1965 (at a wavelength of 73.5 mm: wavelengths less than a metre were then known as "microwave" to contrast them with the much longer VHF wavelengths of World War II radars), an observation confirmed many times since, most notably by the COBE ("Cosmic Background Explorer") satellite measurements around 2 mm which unequivocally demonstrated at high precision that the spectrum really is a black body spectrum. This result was not unexpected, but it is no less astonishing for all that, and its announcement at an Americal Astronomical Society meeting (January 1990) was greeted, extraordinarily, by a standing ovation (see John C. Mather's account in *The Very First Light*, 1996).

It was the fact that the observed $^{1}H/^{4}He$ ratio could be calculated from the observed black-body temperature of the period of thermal equilibrium shortly after Creation (known as the *cosmic microwave background)* that in 1965 suddenly made the Big Bang theory credible, and the most exciting news since Newton explained all cosmological movement by gravity. Now, unexpectedly and almost unbelievably, we have the theoretical means to explain the way the whole Universe has behaved from the moment of Creation!

What actually happened was that the theorists recognised very early on the one hand that the observed helium abundance in the Universe *could not* be accounted for by the stellar processes that explained the abundances of all the *other* elements, and on the other hand that the Big Bang process *could not* be responsible for these heavier elements. Something inhibited the Big Bang nuclear reactions from continuing up the Periodic Table. And the only reasonable way to account for this was to have such intense radiation present in the early Universe that the heavier atomic nuclei were unstable as we have described. The 10^{9} ratio of photons to protons was actually predicted (in 1948 with a faulty argument, and in 1953 with an essentially correct one) by Alpher & Herman, elaborating ideas of George Gamow and using an argument broadly similar to the one above; but not including the details of the nucleosynthesis which was done around 1964 by Zeldovic in Russia, Hoyle & Tayler in England and Peebles in the US, all working independently. Penzias & Wilson did not know about this theoretical work: they were also working independently!

The Big Bang had to be hot! The first creatures were very energetic photons, and the rest followed naturally. As it says: *Let there be light!* Which of these astonishing insights are accessible from the Biblical Creation Account? If someone of the acuity of Augustine can find systematic

ambiguities in that account, how could these very clear ideas of modern cosmogeny ever possibly be extracted from it? For Augustine says (*Confessions*, XII:25):

> When so many meanings, all of them acceptable as true, can be extracted from the words Moses wrote, do you not see how foolish it is to make a bold assertion that one in particular is the one he had in mind?

I should note here that I have sketched only the barest bones of our current cosmogenical understanding. There remain a number of disturbingly open questions, and it is by no means certain that we have yet even a consistent account. However, it is clear that the account is as yet far from complete.

Galileo, and the truth of science

Galileo was condemned because he had claimed that it was *true* that the earth went around the sun, and not *vice versa*. This was held by the Jesuits (whose attitudes were restricted by their Tridentine theology) to be contrary to the straightforward reading of Scripture. I wish to explore the history of this case since it is a valuable model of how both Scripture and scientific ideas should properly be handled – and of the ways in which they can be improperly handled.

We start with the observation that the Jesuits appear to have a point. It says, "The world is firmly established, it cannot be moved" in no less than four places, in David's psalm of praise when the Ark was brought to Jerusalem (1Chron.16:30) and in several of the derivative psalms in Book IV (Ps.93:1; 96:10; 104:5). There are also many other places where it does not quite say that, but which are similar. Now of course, the Jesuits knew that David and his musicians were not particularly interested in the equations of motions of the heavenly bodies: these Scriptures' primary concern is to "Worship the LORD in the beauty of holiness" and to assert that "the LORD reigns" and that his judgements set our hearts free (1Chron.16:29,31; Ps.119:32). However, the Jesuits claimed that a reliable principle of biblical exegesis was to take a passage in all the ways it could bear: first literally, then metaphorically, then allegorically and then morally. Only if the literal meaning was demonstrably inapplicable should it be abandoned. This is similar to the attitude of many commentators today. The Jesuits said that Galileo could not *prove* that the Copernican view was correct, and therefore it was heretical for him to teach it as true, contrary to the clear (and several times repeated) words of Scripture.

What is wrong with this argument? We have to recall that indeed the Jesuits were perfectly correct on one point: in Galileo's day heliocentrism was not proved. The unequivocal proof that the earth does actually move had to wait until James Bradley understood his measurements of stellar light aberration which was a consequence of the proper galactic movement of the earth and from which one can extract the ratio of the speed of light and speed of the earth in its orbit. Bradley published a correct account of his aberration measurement in 1729 (together with an estimate of the speed of light) in the *Philosophical Transactions of the Royal Society*. The size of the aberration (Bradley first measured γ-Draconis) is 20 arc seconds. Bradley also first observed the nutation of the orbit of the earth (*Phil.Trans.* 1748).

What Bradley was looking for was stellar parallax, but this was a much smaller effect and had to wait until Friedrich Bessel (yes, he of the Bessel functions) observed 0.29 arc seconds of parallax for the star 61Cygni in 1838. Aberration is constant (and "large") for all stars, but parallax is a function of the distance of the star, and not many stars are much closer than 61Cygni. Alpha Centauri has the largest parallax, and that is only 0.75 arc seconds.

The other unequivocal proof of the motion of the earth is the precession of Foucault's pendulum, which was first demonstrated only in 1851.

Not only had Galileo not proved that the earth moves, but he incorrectly believed that the earth had a circular orbit, contrary to the work of Kepler, who demonstrated in his *Astronomia Nova* (1609) that the orbit of Mars was elliptical (as was also, presumably, all the other planets of the sun, although this was not explicitly stated until his *Harmonices Mundi* of 1619). *Astronomia Nova* used the extraordinarily precise measurements of Tycho Brahe, which were the best available. But Galileo ignored it although we know that he was aware of it.

We all know, now, that Galileo was right (apart from the circle/ellipse question). But what should we have thought at the time? It seems to me very clear that we must take warning about the danger of a literalist reading of Scripture. God is not glorified by mis-reading his word!

Of course, the Jesuits had their own hidden (or no-so-hidden) agenda. The baleful influence of Tridentine theology that I mentioned above was the effect of the impetus given to the strong Aristotelian flavour of the Thomist theology (that of Thomas Aquinas) that was emphasised by the Council of Trent, which was the theological motor of the Counter Reformation. Heliocentrism was explicitly anti-Aristotelian, and therefore suspected of Lutheran influences. Kepler of course was Lutheran (that he was excommunicated was probably not of great import to the Jesuits), and all his books were strongly Copernican. So underlying the Jesuits' questionable exegesis was the Counter Reformation.

There are no short cuts to doing physics. On the other hand, from before the days of Aquinas doing physics had been recognised as glorifying God by paying attention to the works of his hands. So for example, Adelard of Bath (fl.1116-1142) says in the *Quaestiones Naturales*:

> Whatever there is, is from Him and through Him. But the realm of being is not a confused one, nor is it lacking in disposition which, so far as human knowledge can go, should be consulted.

The mediaeval thinkers established the scientific method much more carefully than they are today generally given credit for: so for example, William of Auvergne, Bishop of Paris (c1180-1249) in his *De Universo* said:

> You should not trust the procedure of the inexperienced who in all cases whose causes they do not know and are unable to investigate, take a facile recourse to the omnipotence of the Creator and call all such things miracles.

John Buridan (c.1295-c1360) did not believe Aristotelian physics, preferring his own idea of "impetus" (a forerunner of *momentum*) to Aristotle's insistence on the existence of intelligences that move the planets and stars in their spheres. In his *De Caelo* he says that:

> God, when He created the world, moved each of the celestial orbs as He pleased, and in moving them He impressed in them impetuses which moved them without His having to move them any more except by the method of general influence whereby He concurs as a co-agent in all things which take place; “for thus on the seventh day He rested from all work” which He had executed by committing to others the actions and the passions in turn

Buridan was read both by Copernicus and by Galileo (who quotes from him nearly word for word to refute Aristotle’s explanation of projectile motion!).

A Special Place in the Universe? – Symmetry Breaking

It is often said that we are on an unremarkable planet in an unremarkable solar system in an unremarkable place in an unremarkable galaxy. So what sense does it make to say that we are children of God, showing his image, breathing his Spirit, and only a little lower than the angels?

It is important to realise that the heliocentrism that displaced our earth from its special place at the centre of the Universe was never an offense to Christianity, only to the Tridentine theology of the

Roman Church, since heliocentrism was an attack on Aristotle and therefore interpreted as Lutheran by the Counter Reformation warriors.

The laws of physics are all symmetric with time (except for the Second Law of Thermodynamics: entropy increases). Also, all fundamental particles are strictly identical: there is no way to distinguish them. Where then does differentiation come from, or the evolution of systems with time? This is a very deep question, and at a deep level it is to do with the structure of complexity. Consider a bowl of water put into the freezer. As a water system there is an infinite amount of symmetry, since all the water molecules are mutually indistinguishable and there is complete translational symmetry: no position in the bowl (ignoring the symmetry breaking of gravity and of the edges of the bowl) is more special than any other position. But as soon as the water freezes (a phase change) the situation is qualitatively different. Now some positions (the crystal lattice positions, where the atoms are) are favoured above others (where no atoms are). So the symmetry of the system has decreased. This is called symmetry breaking, when a phase change drastically reduces the symmetry of the system. It is symmetry breaking that promotes differentiation and the development of complex systems.

The Cosmological Principle (which is very well established observationally) states that our place in the Universe is not special, and that in fact there are no special places in the Universe. Can we therefore infer that we are not special? No, we cannot. This is a category mistake. We are using the word "special" in two different ways, the first in a cosmo***gen***ical context and the second in a cosmo***gon***ical context. Logically they are two completely different ideas. The first says that the Universe has certain fundamental symmetries (which turn out to be very valuable in articulating our present cosmogeny), and the second says that the differentiation that has made our existence possible has given us a significance that can only be articulated at a cosmogonical level.

Actually, it is becoming increasingly clear that, considering our specific case and in no way flouting the Cosmological Principle, we are very special indeed. It would not be surprising if we were the *only* intelligent life in the Universe, and to show Christians have no particular axe to grind it is worth pointing out that it was Christians concerned with establishing the truth of the Gospel against pagan (Aristotelian) thought who insisted on 7th March 1277 (in the 219 propositions of Etienne Tempier, Bishop of Paris) that the earth is not necessarily unique. Our sun is very stable. Our orbit is just so (an astonishing coincidence in itself). Our stellar environment is not disturbing (only a small influence of other stars coming too close would be catastrophic for us). We have lots of water.

The list goes on. It appears that our brains are the most complex things we know of in the Universe, and that the smallest things we know of are to us as we are to the largest things we know of. That is, our scale is central in the Universe. Gravity is just right to favour this central size of ours. The earth has an iron core giving a magnetic field that protects us from the heavy irradiation that would certainly end our lives.

There are many very physical things that make us special. Perhaps one of the most remarkable of these is the very fact that we can measure the age of the Universe, a thing of which we could not possibly have any personal knowledge of any kind. Wittgenstein said, *Not how the world is, but that it is, is what is mystical*, and Einstein said, *The eternal mystery of the world is its comprehensibility*. The most astonishing thing of all is that we, the creatures, are able to comprehend the Creation. How else to explain this, other than that we are indeed made *in the image of God*?

To Save the Phænomena

To save the phenomena is a rather beautiful book published by Pierre Duhem in 1908. Duhem was a highly respected thermodynamicist (thermodynamics is the branch of physics that concerns heat, temperature scales, statistical mechanics, entropy etc), and who also pioneered the study of the history of science and did much to uncover the major contribution of the mediæval

philosophers/theologians to modern science, a contribution that had previously been almost entirely obscured by the anti-clerical prejudices of the Enlightenment.

The first thing a physical theory must do is to *save the phænomena*, that is, explain the observed data, those things that we "see with our eyes" and that "our hands have handled". If there are competing physical theories, all of which "save the phænomena" then we are free to choose between them as we please. But this is not what modern physicists do. Instead they spend great effort articulating the theories more and more carefully, until the various theories make different predictions and can therefore be distinguished.

Galileo (on this account) did not follow proper scientific procedure, since the Ptolomaic and Copernican astronomies both saved the phænomena equally well, and Galileo ignored the Keplerian astronomy which would have made a significant improvement both to calculational accuracy and to the simplicity of the system. This would have to wait until Newton (and I do not believe that the fact that Newton came after the English Civil War and the European Thirty Years War is entirely coincidental). On the other hand, the Roman Church does not come out of it well either since they took political action against Galileo on the basis of a false reading of Scripture.

I have above sketched the modern view of cosmogeny. The reason that this view is convincing is specifically that it saves the phænomena. Not only does it do this, but the history of the development of the modern view shows that in many ways the modern physicists, astronomers and cosmologists are behaving impeccably in exploring the varieties of theories that could be articulated to save the phænomena, and going to considerable trouble to distinguish them and to discover which (if any) are tenable.

For example, Fred Hoyle never did believe the Big Bang theory, but he was the first, together with R.J.Tayler in 1964, to point out that his own stellar nucleosynthesis theory could not explain the observed abundance of helium in the present Universe, while a reasonable Big Bang theory could. (He found other ways to get the static Universe he wanted.) But heretics like this are not resented by other physicists; on the contrary, we like people to take differing views because then our own logic is subjected to much sharper criticism. We approve a plurality of views but we do not believe there is a plurality of truth. One or the other (or both) must be wrong! And the sharpest criticism will reveal the truth.

I have already referred to the exceptionally beautiful book by the Nobel prizewinning physicist Stephen Weinberg: *The First Three Minutes* (1977) in which he describes the meaning of the cosmic microwave background at a popular level, but briefly, lucidly, and without any condescension to the reader, together with arithmetical appendices easily accessible to anyone with basic mathematics (such as A level) which make explicit the rather simple considerations that drive the interpretation. Weinberg says (Ch.5):

> In following this account of the first three minutes, the reader may feel that he can detect a note of scientific over-confidence. He might be right. However, I do not believe that scientific progress is always best advanced by keeping an altogether open mind. It is often necessary to forget one's doubts and to follow the consequences of one's assumptions wherever they may lead – the great thing is not to be free of theoretical prejudices, but to have the right theoretical prejudices. And always, the test of any theoretical preconception is in where it leads. The standard model of the early universe has scored some successes, and it provides a coherent theoretical framework for future experimental programmes. This does not mean that it is true, but it does mean that it deserves to be taken seriously.

Several writers have published extensive, detailed and subtle accounts of how indeed it is impossible to be completely objective: it is an error to believe that one could be. I am thinking of Michael Polanyi's *Personal Knowledge* (1958) and Stanley Jaki's *The Relevance of Physics* (1966) which have both strongly influenced me.

Why should we take any theories seriously before we know that they are true? From one point of view of course there is no need for non-scientists to take an interest in technical discussions until the experts have reached a consensus. But is it sensible to wait that long? Should Newton have bothered to read Kepler's books (which he did) before he knew that they were indeed good science (ie: true)? Well, if he hadn't, then he would not himself have supplied the fantastically powerful theoretical framework that were grist to the mill of the eighteenth century mathematicians who provided the mathematical foundations of the technical advances that actually allowed stellar parallax to be observed.

The issue is, relevance on the one hand and coherence on the other. What set of observations is the theory making sense of? Does it shed new light on them? The issue of truth is interesting, and a little subtle. All scientists believe that the world is really out there, *and* that it obeys rational laws, *and* that they themselves are (potentially) capable of discovering those laws (although they may not always succeed!). However, any particular theory, although it may be objectively valuable in that it saves a certain set of phænomena, is almost certainly *not* absolutely true. But every scientist believes that he would always reject a theory that is demonstrably false in favour of one that is demonstrably true.

The truth is that we (as scientists) will always have only an approximation to the truth. But this approximation may be as much of reality as we can cope with, and can be itself mindbogglingly amazing. Newton's laws for example appeared to apply to *everything* and explain *everything* right up to the latter part of the nineteenth century. Even though the philosophical foundations of Newton's theory are entirely false, Newton's laws are still an excellent approximation for nearly everything we do. All theories are like the curate's egg: good in parts. But the good parts can be very very good!

Minding your own Business

How much information is in the Scriptures? How far can they be pressed to tell us about, say, cosmogeny? The Bible occasionally addresses such questions, obliquely, and one such reference is when St. Paul told the Thessalonians, "We hear that some among you are idle: they are not busy, they are busybodies! Such people we command and urge in the Lord Jesus Christ to settle down and earn the bread they eat." (2Thess.3:11f). St. Paul was a tentmaker: how much help in his training might Ex.35 have been? Perhaps the seafarers might have got some tips from Ps.107? Or farmers concerned about their stock quality might refer to Gen.30? Or merchants needing perspective could look at Rev.18?

Clearly I am being ridiculous. But my point remains. I said there are no short cuts in physics. The physicist must mind his business. He must observe the world and draw coherent conclusions from his observations. There is no point looking to the pages of the divine Word for help: "the Holy Scriptures ... make [us] wise for salvation in Christ Jesus" (2Tim.3:15), not wise in the details of Schrödinger's equation. Paul bids Timothy to be a good workman: "a workman who does not need to be ashamed" (2Tim.2:15), to "not neglect [his] gift" and to "be diligent in these matters, [giving himself] wholly to them" (1Tim.4:14f).

Just as Timothy was bidden to be a good workman, "correctly handling the word of truth" (2Tim.3:15), so every Christian tradesman must be a good workman, correctly handling his materials, from the tentmaker to the physicist.

But then, truth is true, and surely truth is not compartmentalised into some sort of schizophrenic nightmare where on Sunday we go to Church and on Monday to Friday we go to the Bank and on Saturday we go to EuroDisney? True truth must be integrated, allowing us to be "men of respect, sincere, ... [keeping] hold of the deep truths of the faith with a clear conscience" (1Tim.3:8f).

The Scriptures reveal to us Christ Jesus the Lord, in all the splendour and ramifications of that title. They reveal what it is to be kind, and courteous, and just. And they reveal to us a God who is kind and courteous and just through and through, from his fatherly dealings with his children to his delight in the natural world, the work of his hands. When the scientist goes to work, he brings his Christian faith with him not only to govern his relations with other scientists (which must be just and courteous) but also to emphasise that he is honour bound to treat his data as sacrosanct, since it is blasphemous to treat with contempt the Word that has established the phænomena he is studying. The truths for which he is searching may only ever be partially reached, but they are nevertheless true and to lie about them is to sin against the Spirit (Matt.12:31f; Lk.12:10). Woe betide such a man!

The Ancient of Days

The Two Slit Experiment

Consider a large room, large enough to have two large windows. These windows have pairs of heavy curtains, almost closed. It is dark, and the lights are on in the room. Now go away to the other side of the valley, half a mile away, and look back. It is as though light were coming out of two slits.

When Newton published his *Opticks* in 1704 he believed that light came in particles (for rather good reasons), and so it was thought for the next century. But then Thomas Young performed the classical two slit experiment in 1801. This is easiest thought about in two dimensions. Consider a large pond, smooth as a mill pond, divided by a bar, but the bar has two gaps. If a pebble is dropped one side of the bar the ripples will reach the gaps, and then the gaps themselves will act as sources of ripples. And the two sources of ripples will interfere with each other and make a complex and beautiful pattern. For the century after Young's experiment it was thought that light was a wave, an insight confirmed when Heinrich Hertz in 1886 rearranged Maxwell's equations of electromagnetism (1865) to get the wave equation, and then observed radio waves.

Then in 1905 Albert Einstein published three ground-breaking papers in *Annalen der Physik*: the first deriving the Lorentz-Fitzgerald contraction from the assumption of the invariance of the speed of light in inertial frames of reference ("Special Relativity": this is where $E=mc^2$ comes from), the second establishing that Brownian motion is a necessary statistical result of the atomic nature of liquids, and the third (which concerns us) establishing that light behaves as a particle (a photon) in the photoelectric effect.

So is light a wave or a particle? One could pose this same question another way by asking which slit the photon goes through in the two slit experiment. Now here is where it gets interesting. We now have extremely sensitive light detectors, able to detect single photons. So let us turn down the intensity of the light striking the two slits such that at any one time there are either no photons in the apparatus or only one photon in the apparatus (this was first done by Geoffrey Taylor in 1909). Does the interference pattern still appear (after waiting long enough)? *Yes it does!* One might think that the photon has to go through either one or the other of the slits, and then for the interference pattern to appear the interference has to be either with a photon long gone or with one yet to come. This is weird!

One can play further, and arrange a very cunning apparatus such that there are sensors on the slits to tell us which slit any particular photon has gone through. But in this case *there is no interference!* We are driven to the conclusion that, the photon is a wave *provided we do not look to see which slit it goes through*, but if we do look then it is a particle!

This baffling experiment is one of the most well established things in the world, it is better known than your birthday. It also works for "real" particles in exactly the same way: the same observations are made for electrons, protons and heavier particles. In the quantum world matter and energy are mixed up, and matter behaves in a very weird way.

The Bands of Orion

There is a tendency for Christians to turn from the baffling big wide world to the comforting familiarity of the Scriptures, and imagine that they can understand the well known text. "He says this here", they say, "and he means that". I have described the two slit experiment because it is very simple but, as Richard Feynman was fond of saying, all of quantum mechanics in all its weirdness can be gleaned from carefully thinking through the implications of this single experiment. Augustine commented about people (*Confessions* XII:27)

> limited ... by their attachment to the familiar material world around them. These people are still like children. But the very simplicity of the language of Scripture sustains them in their weakness as a mother cradles an infant in her lap. ... But if any man despises the words of Scripture as language fit for simpletons and, in the stupidity of pride, climbs out of the nest where he was reared, woe betide him, for he shall meet his fall. Have pity on such callow fledgelings, O Lord, for those who pass by on the road may tread them underfoot. Send your angel to put them back in the nest, so that they may live, and learn to fly.

God asks Job out of the storm, "Can you bind the beautiful Pleiades, or loose the bands of Orion?" (38:31). How much do we understand? Of one thing we can be sure: Moses was highly intelligent, and it is guaranteed that there are many layers of meaning in what he wrote. Probably he meant more than we will ever extract from the text. But a part of meaning is also ambiguity, which can be (and in the Scriptures invariably is) deliberate. This was explored by the Metaphysical Poets, and is one aspect where the King James translators definitely improved on Tyndale and the Geneva Bible. The text is frequently ambiguous, and a good translation will preserve this ambiguity, avoiding interpretation. We have seen that Augustine commented on biblical ambiguity extensively in the *Confessions* specifically in the context of his discussion of this first Creation account.

On the other hand, there is also ambiguity in science. But here there is a difference. Where in Scripture ambiguity puts an absolute limit on what the text can be pressed to say, in science ambiguity is taken as a spur both for better theory and better observation. Stephen Weinberg in his *The First Three Minutes* makes interesting comments on why it took so long to look for the cosmic microwave background (the "missed opportunity"). He says (ch.6):

> This is often the way it is in physics – our mistake is not that we take our theories too seriously but that we do not take them seriously enough. ... The most important thing accomplished by the ultimate discovery of the 3K radiation background in 1965 was to force us all to take seriously the idea that there *was* an early universe. I have dwelt on this missed opportunity because this seems to me to be the most illuminating sort of history of science. It is understandable that so much of the historiography of science deals with its successes, with serendipitous discoveries, brilliant deductions, or the great magical leaps of a Newton or an Einstein. But I do not think it possible really to understand the successes of science without understanding how *hard* it is – how easy it is to be led astray, how difficult it is to know at any time what is the next thing to be done.

Physical theories are *numerical*: you can make specific and concrete predictions from them. All theories must be approximations and in principle it is possible for any theory to be overturned. But I do not believe that we will ever be forced by the observations to return to a flat earth theory, or to the phlostigon theory, or to an eternal Universe theory. Nor do I believe that the current estimated age of the Universe, independently calculated as it is in a variety of ways, will ever get significantly shorter than 10^{10} years or so.

Roger Penrose has commented extensively on fashion in science, in *The Road to Reality* (2004), a book in which he also deeply analyses the measurement problem which is lurking in paradoxes such as *Schrödinger's Cat.* Penrose believes that the measurement problem remains unresolved, and therefore that quantum mechanics is not yet properly understood. He expects yet another revolution in our understanding! He says (§34.4):

> We see how strongly matters of scientific fashion can influence the directions of theoretical scientific research, despite the traditional protestations from scientists of the objectivity of their subject. Nevertheless, I should make it absolutely clear that the apparent lack of objectivity is not a fault of Nature herself. There is an objective physical world out there, and physicists correctly regard it as their job to find out its nature and to understand its behaviour. The apparent subjectivity ...[is] simply [a] feature of our groping for this understanding, where social pressures, funding pressures, and (understandable) human weaknesses and limitations play important parts in the somewhat chaotic and often mutually inconsistent pictures that we are presently confronted with.

The Days

Now at last we are ready to consider what is meant by "day" in the first Creation account. I say that the text itself compels us to the conclusion that indeterminate times are meant. The reason is that for Moses, a day is a length of time *defined* by the motion of the sun: for him a day is, and can only be, a solar day. But since in the first Creation account the sun is created only on the fourth day, previous references to "day" can only be figurative – a manner of speaking. And therefore, in this account all references to "day" are equally figurative. This is a very old argument, and the literalist argument that irrationally asserts that a day is 86400 seconds long, and that the moment of Creation is therefore 6pm on 26th October 4004BC, is a modern novelty.

My view, at which I arrived independently by considering only the text itself, has been orthodox since at least Augustine's *City of God* (published 426AD):

> (Book XI, chapter VI) *That the world and time had both one beginning, nor was the one before the other:* ... no time passed before the world, because no creature was made by whose course it might pass. But it was made with time, if motion be time's condition, as that order of the first six or seven days seems to show ... Of what fashion those days were, it is either exceeding hard or altogether impossible to think, much more to speak.
>
> (Book XI, chapter VII) *Of the first six days that had morning and evening ere the sun was made:* As for ordinary days, we see that they have neither morning nor evening but as the sun rises and sets. But the first three days of all had no sun, for that was made on the fourth day. ...

Augustine comes to the conclusion that time is *motion of something*: and this insight is reflected in our modern definition of the second, which is a certain number of vibrations of the cesium atom (oscillations between the two hyperfine levels in the ground state of ^{133}Cs, to be precise). But he would have been astonished (and delighted) at the modern resolutions of all those paradoxes that so greatly baffled him. I am greatly encouraged that my reasoning is (independently) exactly the same as his. True reasoning is equally true a thousand years ago, or a thousand years hence. Truth is not a function of time.

It is worth pointing out, parenthetically, that Moses not only very deliberately relegates the creation of the sun and moon to the fourth day, but also declines even to *name* them: this is specifically to signal emphatically to the reader that God is *prior* to all the heavenly bodies, and that they are only creatures like all other creatures contingent upon his Word. The Israelites were warned in their earliest texts not to follow the pagans in their idolatrous worship of these heavenly bodies, a practice ubiquitous in the surrounding nations.

We may ask, where else in Scripture is "day" used figuratively? Is this indeterminate usage in the first Creation account singular, or does the Spirit also use this poetic language in other contexts?

First, and most obviously, the only psalm of Moses in the Book of Psalms says:

> For a thousand years in your eyes
> are like yesterday gone
> like a watch in the night (Ps.90:4; transl. Robert Alter 2007)

Not only does Moses apply a factor of a third of a million, but he emphasises that this factor itself is indeterminate! And it is no use to complain that Moses is not using the same word as in the first Creation account (ʾethmôwl in Ps.90 instead of yôwm in Gen.1) since the entry (3117) in Strong's Concordance (KJV) for yôwm shows that it is a very general word used in many ways with a wide range of meanings:

> from an unused root meaning to *be hot*; a *day* (as the *warm* hours), whether literally (from sunrise to sunset, or from one sunset to the next) or figuratively (a space of time defined by an associated term, [often used adverbially]:--- age, +always, +chronicles, continually (-ance), daily, ([birth-], each, to) day, (now, a, two) days (agone), +elder, ×end, +evening, +(for)ever(-lasting, -more), ×full, life, as (so) long as (... live), (even) now, +old, +outlived, +perpetually, presently, +remaineth, ×required, season, ×since, space, then, (process of) time, + as at other times, + in trouble, weather, (as) when, (a, the, within a) while (that), ×whole (+age), (full) year(-ly), +younger

It is interesting to me that Peter both quotes Moses and inverts him: "with the Lord a day is like a thousand years, and a thousand years like a day" (2Pet.3:8), and note that the word used for "day" here – *hemera* – is the same as used in Gen.1 in the LXX. Also, the LXX also uses *hemera* in a phrase for "yesterday" in Ps.90:4 (*hemera e echthes*). God has created time: time is his creature which he handles as he chooses. And when he speaks of a *day* he may be speaking concretely, or figuratively, or allusively, or poetically. We are no longer children: he expects us to pay attention!

This same understanding is evident when the writer to the Hebrews glosses Ps.95:7 in the extended passage of chs.3-5. Critical for us is Heb.4:8ff:

> ... if Joshua had given them rest, God would not have spoken later about another day. There remains, then, a Sabbath-rest for the people of God; for anyone who enters God's rest also rests from his own work, just as God did from his. Let us therefore make every effort to enter that rest

Apparently, we are now, still, in the seventh day of creation, the day of the rest of God. We are saved by grace, not by works, therefore we must be in rest. God has done the work, in some sense before the world began. In any case, the Today (*semeron*) of which the Psalmist and the writer to the Hebrews speaks is certainly not 86400 seconds long.

And then, why does Daniel refer to the *Ancient of Days* (Dan.7:9,13,22)? Is he not referring to the days of creation, that is, all of time (on the basis that *Today* is the Sabbath-rest of God, as we have seen)? Daniel is looking forward to the Day of Judgement, to the Day of Wrath (Zeph.1:15), where the Son of Man will be given all authority to judge by the Creator of all things, the Creator of the heavens and of the earth and of time itself: Almighty God. And then afterwards, God will create the Eighth Day, the day of the new Creation. My hair stands on end (Job 4:15)!

Let us summarise. There is no justification in the text, or in the context, or in the usage, or in the syntactics, or in the semantics, or in logic for the assertion that the *days* in the first Creation account refer to periods of time of 86400 seconds. It is absurd to assert any such thing, and has been recognised as such for thousands of years. The discovery of the age of the Universe comes not as any challenge to the text of Scripture but as a fascinating insight into the inexhaustible imagination of our wonderful God.

Conclusions: the Heavens declare the Glory of God

I went to University to find out how God made the world. I found out many things, and I was satisfied. But as time has gone on, the more I found out the more astonished I became.

We have considered the question: Why not take Genesis 1 as history and try to put together a cosmogony that fits it? We have seen that Genesis is certainly a cosmogonical account, and thereby cannot possibly be a historical account, since history, to be history, must have eyewitnesses. We have seen, moreover, that considering Genesis as a text, it is a sophisticated text with demonstrable self-awareness, and that from a textual point of view it is quite different from clearly historical texts in the same book.

We have seen that a Christian cosmogony requires that the Universe has a *finite* age, where we drew a distinction between a cosmo*gony* which speaks about the beginnings and a cosmo*geny* which describes the development of the cosmos. We have seen that the Christian view of man as *"in the image of God"* makes it credible that we can understand the Universe, that is, develop a coherent cosmogeny.

In fact, there is now for the first time a credible and well articulated cosmogeny with very substantial experimental support that enables us to put an age on the Universe. It is worth pointing out that when the prevailing cosmogeny favoured an eternal Universe (contrary to Scripture) there was neither any experimental support for such a position nor any prospect of getting any such support. In fact, it was not believed that a scientific cosmogeny under these conditions was even possible. Therefore, not only is the new cosmogeny explicitly consistent with Scripture, but the very fact that it now exists is itself explicable only in the light of Scripture, reflecting as it does our special relationship with God.

Nothing in what we have said makes our understanding of Scripture in any way contingent upon current scientific beliefs, except of course that an eternal Universe is inconsistent with Scripture. But it was only when this axiom (of the static Universe) was abandoned that a scientific cosmogeny became accessible, and there seems no prospect of this new understanding becoming reversed.

As Christians we must take history seriously: the historical truth of the Gospels is the bedrock of everything we believe. And taking history seriously implies also taking theological history and scientific history seriously too. We have explored both of these, seeing on the one hand that the classical view of the first Creation account in Genesis that I have propounded has been forcefully and elegantly put in terms equivalent to mine at least since Augustine. This is surprising since Augustine's interests and his intellectual environment was apparently entirely different from ours. On the other hand our explorations of scientific history have made clear the ontological place that science has in our understanding of knowledge itself, and of knowledge of the Scriptures in particular. I have demonstrated that my view is coherent, and consistent with everything we know.

The new cosmogeny makes us only more aware of the truth of David's majestic cry: *The heavens declare the glory of God.*

C.Jeynes, Guildford, 21st March 2009 (revised 23 & 27 March & 17 April 2009)