COMMITTEE VI
The Universe and Its Origin:
From Ancient Myth to Present Reality
and Fantasy

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GIANT COMETS AND THEIR ROLE IN HISTORY

by

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"In the West a star shall shine, which they call a comet, a messenger to men of the sword, famine and death."

The Sibylline Oracles.

"God, whose dwelling is in the sky, shall roll up the heaven as a book is rolled, and the whole firmament in its varied forms shall fall on the divine earth and on the sea; and then shall flow a ceaseless cataract of raging fire and shall burn land and sea, and the firmament of heaven and the stars and creation itself it shall cast into one molten mass and clean dissolve. Then no more shall there be luminaries, twinkling orbs, no night, no dawn... no spring, no summer, no winter, no autumn."

The Sibylline Oracles.

"You [Greeks] are all young in your minds," said the priest, "which hold no store of old belief based on long tradition, no knowledge hoary with age. The reason is this. There have been, and will be hereafter, many and divers destructions of mankind, the greatest by fire and water, though other lesser ones are due to countless other causes. Thus the story current also in your part of the world, that Phaethon, child of the Sun, once harnessed his father's chariot but could not guide it on his father's course and so burnt up everything on the face of the earth and was himself consumed by the thunderbolt - this legend has the air of a fable; but the truth behind it is a deviation of the bodies that revolve in heaven around the earth and a destruction, occuring at long intervals, of things on earth by a great conflagration.... Any great or noble achievement or

otherwise exceptional event that has come to pass, either in your parts or here or in any place of which we have tidings, has been written down for ages past in records that are preserved in our temples [in Egypt]; whereas with you and other peoples again and again, life [had only just] been enriched with letters and all the other necessities of civilization when once more, after the usual period of years, the torrents from heaven [swept] down like a pestilence, leaving only the rude and unlettered among you. And so you start again like children, knowing nothing of what existed in ancient times here or in your own country.... To begin with, your people remember only one deluge, though there were many earlier; and moreover you do not know that the noblest and bravest race in the world once lived in your own country. From a small remnant of their seed you and all your fellow citizens are derived; but you know nothing of it because the survivors for many generations died leaving no word in writing...."

Timaeus (Plato; tr. F.M. Cornford).

"We still tremble today from the consequences of the deluge, and our institutions, without our knowing it, still pass on to us the fears and the apocalyptic ideas of our forefathers. Terror subsists from race to race, and the experience of the centuries can only weaken it but cannot make it entirely disappear."

L'Antiquite dévoilée par ses usages (Boulanger, 1766)

Such visions in the sky and the once doom-laden world of our ancestors now invite derision and contempt. Our conception of history

obliges us to recognize a Renaissance that lifted the human spirit and an Enlightenment that provided new understanding. Inevitably therefore, we are trained to accept an earlier age characterised by morbid imagination and lack of education. As a consequence, we learn very early to put aside all the fire and brimstone, the signs from heaven and the talk of armageddon. If however we ever stop to question this conditioning of our reflexes, we may realise that the rejection of the doom-laden world has only as much validity as any of the arguments that were deployed during the Renaissance and the Enlightenment to overcome celestial portents. Evidently, if we are to have any confidence in our response, it is these arguments that we should examine.

During much of recorded history, it has been Aristotelian dogma that helped to keep comets in their place. Admittedly the population at large has until quite recently remained somewhat fearful at the appearance of comets but men of letters learned long ago to be a little more circumspect. In Aristotle's scheme of things, comets were thought to originate in the Earth's atmosphere and were probably of no greater importance than a passing shower of rain. Eventually it was the Danish astonomer Tycho Brahe however who caused the picture to be changed: thus, by making careful observations of the comet of 1577, he discovered that its nearest point of approach was well outside the sub-lunary zone. Conceivably then, comets were instruments of divine vengeance after all but those of the time who were less eschatologically inclined took a more prosaic view. Kepler for

example, simply assumed comets were sweeping past the Solar System in straight lines, whilst Galileo, anxious perhaps to be rid of all the humbug, treated them as mere optical illusions! The latter was not a particularly tenable viewpoint however, so we find Newton subsequently preferring the Keplerian assumption; though not so much out of conservatism as it happens, but because he wished to avoid comet encounters doing any damage to his perception of the Solar System. Thus Newton, like Aristotle before him, considered the Solar System to be a divine creation, set to run like a clockwork machine; and stray comets passing through could obviously put it very much at risk. In 1681 however, another important comet was observed, this time by Flamsteed, and it was without doubt in a near parabolic orbit, coming well within the planetary system. Never slow to come to terms with the inevitable, Newton had to rapidly adjust his stance - the orbits of comets were obviously now just another aspect of the divinely ordained law of gravity. But with a subtle change of emphasis, Newton now insisted that encounters with planets should be seen as providential rather than catastrophic events. Very little attention has been given to this interesting circumvention of Newton's, but so far as its impact on science is concerned, it has been almost as significant as his law of gravity. Let us follow the matter a little further.

Newton's Other Law

Newton was of course not alone in reflecting on these questions and by this time the possibility of a disaster through cometary impact

on the Earth had become a matter for general debate. Scholars seriously questioned whether the conflagration of Phaethon and the flood of Deucalion or Ogyges had been caused by a celestial body. The flood of Ogyges was noted for example as having been attributed to the arrival of a comet Typhon, and there was also a connection with the Bible for Roman historians had made the plagues of Egypt a contemporary event. Such issues as whether the floods of Noah, Ogyges and Deucalion were one and the same were also raised, and the outcome of all these enquiries was a growing concern for terrestrial catastrophism and ancient chronology. On the one hand, it seemed that historical studies may help to determine the periods of returning comets, and on the other hand, it seemed that one could use such periodicity to plot the course of major historical events. Then by chance, another comet appeared in 1682 and Halley was one of the first to identify it with recent well authenticated apparitions in 1531 and 1607, thus providing a demonstration of the methods to be applied. This particular comet was of course to take Halley's name in the fullness of time (following its predicted return in 1758) but Halley's more immediate interest was in deriving a period for the comet of 1681. A value of 575 years was obtained (incorrect as it happens) which Newton's successor in the Lucasian chair at Cambridge, Whiston, made use of in calculating earlier apparitions. Notable among these was one at Caesar's death in 44 BC and another corresponding to Noah's flood in 2342 BC. Indeed, Whiston's book describing these researches, which he dedicated to Newton, was entitled 'The New Theory of the Earth',

and the latter came rapidly to be seen by clerics and natural philosophers alike as a quite major step forward in the advancement of knowledge. Seemingly for the very first time, observational science and received biblical knowledge were in excellent accord. It was a history of catastrophe moreover, and the day of judgement could even be at hand!

Whiston however did not see it this way. He thought the course of events required a more matter-of-fact interpretation of the Bible, and that it indicated a less prominent role for Christ. This was taken by his contemporaries however to be an attempted revival of the old Arian heresy and the clerical establishment soon sought to distance itself from Whiston. In the meantime, Newton took it upon himself to emphasise what he considered to be the fundamental role of comets, namely their ability to deposit new material on to the stars and planets and their potential for doing good to the Earth! The calm voice of reason thus spoke! Scaremongering was naturally added to the list of Whiston's faults and it was not long before the latter was dismissed from his post. Even if there was no conspiracy, the message from the law-makers was clear: the world was not to be disturbed and Newton's new ground rules for comets were the ones that had to be observed. The return of Halley's comet in due course, in accord with gravitational law, then merely served to enforce the new paradigm - as also did Lexell's comet, some years later, when it passed by the Earth without any noticable gravitational effect. The latter in fact was good evidence that comets were very much smaller then planets, thereby diminishing still further any concern that still lingered over the

menace that comets seemed to present. Thus, by the end of the eighteenth century, Newton's view of comets had gained considerably in strength and we find Herschel, a very influential atstronomer, putting forward an almost teleological view of comets as a necessary adjunct to his new discoveries regarding the distribution of stars in the milky way. It was Herschel's opinion for example that comets were to be taken as essentially interstellar objects purposely weaving their way among the stars, including the Sun, with the specific intention of replenishing their fuel, and if necessary, planetary life as well. Newton's theory had therefore developed rather successfully into an all-embracing cosmological view of some permanence and continuity to which the masters of an orderly empire could easily subscribe. It was a vision that clearly deserved royal patronage.

The new discoveries of meteorites and minor planets which happened to come at this juncture might have seriously disturbed the status quo by raising the spectre of other kinds of celestial hazard and they were indeed ferociously opposed; but the generally small size of the former and the confinement of the latter to a belt between the orbits of Mars and Jupiter eventually allayed any fears. Thus there was little doubt in anybody's mind that the natural philosophers contributing to the Enlightenment had been broadly right in considering only the effects of comets, and even if by the middle of the nineteenth century, some questions were being raised concerning Herschel's view of the interstellar nature of comets because of the failure to observe any on hyperbolic orbits, the established view of

catastrophism was by now being upheld in its essentials by the growing realization that comets trapped into short-period orbits rapidly decayed into meteor streams. It had indeed come to be appreciated that Nature was capable of rendering comets more or less automatically harmless by turning them into dust which fed into the atmosphere to be witnessed as shooting stars. Thus, well before the middle of the last century, Newton's long established replenishment theory of comets was considered to have been completely vindicated. Celestial portents had been well and truly tamed!

Entrenchment and Doubts

The confidence of nineteenth century physicists is legendary. To comprehend this, one has to appreciate the atmosphere of commitment and faith that had grown up around Newtonian science. Thus, within about a hundred years, a situation had emerged in which remarkably simple mathematical laws (those of motion and gravity) were appearing to provide absolute control over the forces of Nature. Such a situation was virtually unprecedented and created an approach to (Newtonian) science that was hardly distinguishable from religious zeal. Admittedly, if one were to examine the details, there were some difficulties with the mechanical aether and the explanation of electromagnetic phenomena but the solution of these difficulties was widely assumed to be just a matter of patience and time. The mechanisms involved were, it was thought, likely to be simple and would fall easily into place once there was a proper grasp of all the relevant experimental phenomena. With our knowledge of the surprises

yet in store and of the great upheavals in physics that were to come, it is difficult perhaps to grasp this very real feeling of mastery over the forces of Nature that prevailed in the nineteenth century. And difficult moreover to recognize that this feeling of mastery also extended to the astronomical environment. Here it was obviously Newton's 'other law' and the presumed harmless character of that environment that gave rise to the feeling. Thus, whilst gravity could be seen to pervade the universe and to be providing a smooth undercurrent of physical control over the behaviour of matter, it was also possible so far as comets were concerned to draw a clear demarcation between the unharmed Earth on the one hand and the non-interventionist cosmos on the other. The impact of this revitalised Aristotelian arrangement was considerable for never before had there been created such an impression of security in relation to the astronomical surroundings. The new benevolent cosmos underwritten by Newtonian laws could even be seen as the ultimate triumph of a tranquil christian tradition over fiercer judaic traditions and those of presumed less enlightened faiths. It was no accident of course that an anglo-saxon protestant dominated empire at its zenith should have provided the setting within which the universe was to be comprehended. With everything under such control, it is no surprise that Earth scientists and biologists now felt free to explain terrestrial evolution and biological evolution without the hindrance of any thoughts of external interference. In a like manner historians and social scientists modified their views of historical evolution and

looked more and more to human factors dominating the course of events.

There is a widespread and mistaken view nowadays, especially amongst Earth scientists and Biblical fundamentalists, that the issue of catastrophism in Earth history was decided at this epoch (ie the middle of the nineteenth century) by geologists and biologists debating the forces of natural selection. In actual fact, the uniformitarian framework had already been agreed by astronomers, as we have seen, and it had simply become a matter of convincing oneself that contemporary terrestrial processes were enough to explain evolutionary change, as revealed for example by the fossil record. The geologist Lyell and the natural historian Darwin and their followers took the lead over this issue because they were not particularly bound by any biblical or physical conventions regarding the age of the Earth, but insofar as they needed support for the slow action of virtually undetectable forces, the physical scene had already been set. Likewise, it is hardly accidental that social history was now presumed by experts to be due to the action of unseen social forces acting either progressively, through a consensus of similarly oppressed minds, or randomly, through leads from solitary disturbed minds. Indeed, with the problems of physical science apparently on the verge of resolution, the social sciences seemed now to acquire a new attraction; a new cultural division arose in which the mastery over physical science was taken for granted and a justification existed for the exclusive study of the humanities. Leaders of the new thinking (Marx, Freud,...) naturally gravitated to

the country of origin of the new paradigm... The point to be made here is that none of these developments moulding the twentieth century outlook on the nature of the world could have arisen without the vital sense of control over natural phenomena that had been acquired through physical and astronomical science. Celestial portents had been more than just tamed, they had become unthinkable.

Although astronomical facts lay at the root of this formidable new universe, the apparent control over the forces of Nature that came to be so widely accepted, seemed eventually to give rise to a somewhat dismissive attitude on the part of physicists towards some aspects of astronomy. Unlike earthbound experiments where some degree of regulation is possible, the complexities of the astronomical scene have to be accepted more or less a face value, and one can detect a growing impatience with the more speculative style of enquiry that is then necessary. This attitude eventually came to a head during the middle decades of the present century when Rutherford spurned the efforts of Eddington to set cosmological science on a secure footing and a confrontation took place between physics and the sibling discipline of astrophysics. Co-existence was always possible however so long as astrophysicists confined their activities to the astronomical scene and physicists and others confined their activities to the terrestrial scene. In practice this is exactly what happened: physicists concentrated on the structure of fundamental particles and the properties of matter that could be studied in the laboratory; whilst astrophysicists concentrated on the properties of stars and

larger systems like galaxies and the universe as a whole. Only in recent years have leading practitioners in these fields sealed this happy arrangement by developing a mutual interest in the common forces operating in the deepest recesses of nuclear structure and in the most inaccessible phase of the universe's supposed evolution. While it is a source of strength to these practitioners that their inevitably unconstrained theorising in these fields has little or no impact on other areas of knowledge, it is quite remarkable that such developments should have taken place with little or no regard for the more obvious and more accessible area of overlap between physics and astrophysics, namely the planetary and interplanetary region where comets make their appearance. The fact is however that for at least half the present century and despite the great advances in physics meanwhile, the planetary system and its environment were regarded as virtually inert and of little fundamental significance to science. Indeed, this was so much the situation mid-way through the twentieth century that when the opportunity arose to pursue planetary and interplanetary investigations with space-probes, physicists and astrophysicists were probably among the last to take much interest. It was as if Newton's 'other law' had proved itself such a perfect recipe for maintaining order that there was a general reluctance to uncover anything that might disturb the status quo.

That this attitude undoubtedly prevailed is illustrated rather well by the scientific response at this time to an unheralded attempt by Velikovsky to reinstate the ancient fear of comets. This author in

effect sought to revive the discussion of catastrophism that took place during the period of Enlightenment but he was not able to identify the irrational component of Newton's arument (ie the replenishment theory) and laid himself open to easy scientific criticism by choosing to doubt various aspects of gravitational theory. During the ensuing vitriolic exchanges of opinion however, it also became apparent that many modern scientists were defending a fundamentally innocuous role for comets without an entirely clear reason for so doing. Thus, although there was evidence that comets could produce meteor streams, the progenitors in many cases had not been detected and it was not beyond the bounds of possibility that invisible remnants of a more destructive kind were also produced by comets. It was indeed obvious that a century - old assumption was without a secure observational basis and that there was no absolute guarantee that Newton's 'other law' is correct.

A Dilemma Resolved

By this time of course, the space age had arrived and the importance of past impact cratering on planetary surfaces had begun to be recognized. The extent of the asteroidal population in Earth-crossing orbits was also being revealed. It was not long therefore before these new discoveries were thought to imply a cause-and-effect relationship. Previously unobserved bodies greater than a kilometer in size were indeed impacting on the Earth every million years or so, on average. This was certainly more frequently than observed comets but still seemed to be of such little consequence on the timescale

of historical events that it was considered rather unlikely to have any bearing on the subject of catastrophism. The new findings tended therefore to excite little attention and would perhaps have continued in this vein had not the source of Earth-crossing asteroids proved rather problematic. Thus, right from the moment of discovery, it was assumed that Jupiter must be responsible for deflecting these Earth-crossing asteriods from their original orbits in the asteroid belt. The assumption has persisted until the present despite a continuing failure to demonstrate how the mechanism works. Under the circumstances, one might have expected the alternative possibility, that Earth-crossing asteriods are 'dead comets', to be welcomed but the belief that comets always turned into dust was evidently still too strongly imprinted to allow such a change of view. Not that the resistance to this change was necessarily irrational for by this time, the presumed physical nature of comets had been calculated so as to conform with other developments in modern astrophysical theory. Accordingly, all observed comets were now assumed to have been originally produced far out in the primordial solar nebula where the formative interstellar medium was thought to have been sufficiently compressed to allow small particles of dust to accrete into larger bodies whilst also absorbing a variety of more volatile chemicals. Such a process required comets to be very cold throughout their lifetime and there was in principle no qualitative difference between ordinary kilometre-sized comets and the occassional giant comets with diameters greater than 100 kilometers. Thus, there were no grounds

for supposing there was any observable difference between the meteor streams produced by ordinary comets and giant comets, as required for the presumed uniformitarian astronomical environment of the Earth. Neither was there any good reason for supposing comets could produce asteroids.

According to this rather gentle astrophysical scenario, the formation of the primordial solar nebula is thought to have taken place under conditions of cold gravitational collapse during which the surplus turbulent energy is steadily carried away by radiation. However, it is also possible to envisage a more violent astrophysical process in which comet-like planetesimals condense out of a hot dissipating primordial system wherein the surplus turbulent energy is carried away by ejected material. Under these circumstances, giant comets in particular are highly differentiated chemically and are qualitatively very different from the smaller more ordinary comets. Giant comets indeed then seem to be very like the primitive bodies out of which observed meteorites are supposed to have formed, but of even greater significance is the fact that contemporary examples (eg Chiron) may produce meteor streams which develop by progressive fragmentation through asteroidal bodies of smaller and smaller size. Such meteor streams are potentially much more dangerous than conventional meteor streams since they are fed by a huge swarm of small asteroids of the 'Tunguska' type which may encounter the Earth from time to time producing violent fireball storms and a battery of great explosions in the hundred or thousand megaton class - Nature's

equivalent of a devasting nuclear war! The frequency of such catastrophic encounters depends both on orbital coincidences between an evolving giant comet and the Earth and on the rate of arrival of giant comets in Earth-crossing orbits. The latter is largely controlled by Galactic interactions and the various predicted periodicities are shown in Table I

Table I

Predicted periodicities in the terrestrial record

Approximate periods (in years)	Physical origin
$10^{0.5 - 2.5}$	Giant comet orbital commensurability with Earth.
$10^{3.5}$	Giant comet orbital precession.
$10^{4.5 - 5.5}$	Recurrence time for giant comets
$10^{6 - 8}$	Stochastically distributed intervals associated with disturbances of the Sun's comet cloud by molecular clouds in the Galactic plane.
$10^{7.5}$	Vertical oscillations of the Sun's orbit through the Galactic plane.
$10^{8.5}$	Radial oscillations in the Galactic plane
10^{9}	Beat frequencies associated with recurrent production of molecular cloud systems

According to our current knowledge, it is very likely that many of these frequencies are impressed upon the terrestrial record, so the Earth's evolution by implication is catastrophic. However the physical mechanisms involved are by no means fully worked out and some aspects of this picture are necessarily speculative at the present time. The obliteration of dinosaurs sixty five million years ago by an asteroid epitomises a view of this kind of evolution which has recently caught the popular imagination. Nevertheless the broad picture is reasonably clear: successive giant comets arriving in circumterrestrial space will each produce a huge meteor stream which for an interval of 10,000 years or so is responsible for periodically maintaining a dense stratospheric dust veil and inducing an ice-age; during the subsequent interglacial, the giant comet declines to near invisibility whilst experiencing disintegrations which give rise to periodic terrestrial bombardments mostly by bodies in the Tunguska and super-Tunguska class. The question that now confronts us is whether Newton's 'other law' is correct, or whether there are indications in the Earth's recent history and its current environment that the more violent scenario really applies. Such indications, if present, would tell us that modern astrophysical theory, through its predilection for the non-interventionist cosmos, has succeeded in developing a wholly false view of the origin of comets, predicated on our current understanding of the nature of the universe. The extent to which it would be necessary to preserve this understanding of the universe would then appear to become an open question.

The Most Recent Giant Comet

The largest if not the brightest meteor stream in the sky is the so-called Taurid-Arietid stream. It approaches the Earth by night from the (celestial) west in the months of November/December and by day from the north during May/June. Since the Earth's crossing time for most other meteor streams is just a few hours, there is a considerable contrast between the breadth of the Taurid-Arietid stream and that of other streams: volume for volume and mass for mass, the source of the Taurid-Arietid stream may not be far short of a million times larger that that of a typical stream. And since a typical comet is a few kilometers in diameter, the ultimate source in this case may easily be a giant comet a few hundred kilometers in size. The material in this stream mostly circulates in elliptical orbits with periods of around 3 years within the path of Jupiter. Most other meteor streams have longer periods than this but a substantial fraction tend to concentrate in the same part of the sky as the Taurid-Arietid stream, thereby raising the possibility of a common origin (ie fragmentation of a single parent body) and a subsequent more rapid dispersal of those streams that cross the orbit of Jupiter. It has recently been noted that the Taurid-Arietid stream coincides with an even broader stream of smaller particles which are similar in character to those of the zodiacal cloud, and it is likely therefore that this stream is ultimately the major current source of dust in the terrestrial environment. Comet Encke (period = 3.3 years) is a prominent member of the Taurid-Arietid stream, and a significant proportion of the known

population of Earth-crossing asteroids (around 10 per cent) seems also to be identified with the stream. Indeed one of these asteriods is somewhat cometary in appearance and there is a growing impression that the stream derives from a cometary progenitor and that it must then progressively disintegrate into a variety of asteroidal debris. The Tunguska body of one hundred, thousand tons is a case in point: it struck the Earth on the morning of June 30 in 1908 and was almost certainly a member of the stream. It is also established now that the stream includes many somewhat smaller bodies with masses in excess of a ton for these have been detected striking the Moon following the placing there of several seismometers by Apollo astronauts. Such missiles appear to have spread throughout the stream during approximately the last 20,000 years from a dense swarm at its core. The outer region of the latter was in fact encountered during a week-long penetration at the end of June in 1975.

To sum up, the wide range of material now observed in the Taurid-Arietid stream is consistent with a giant comet for its source and a history of successive fragmentations periodically replenishing the dense core of the stream and enhancing the zodiacal cloud. Such a history was in fact conjectured for the stream over thirty years ago when astronmers Whipple and Hamid accurately retrocalculated the orbits of a number of meteors to indicate that several major fragmentations had taken place during the last 5000 years. The most significant of these events took place around 3000 BC due to an encounter in the

asteroid belt and another was deemed to have occurred around 500 AD, with possibly yet another in the second half of the second millenium BC. The epochs around 3000 and 1300 BC in particular correspond to significant deteriorations in the global climate for two or three centuries or more - at least, to the extent that global climate is reflected by the advance and reteat of the northern limit of forestation in Canada and by the rise and fall of sea-level around England. It is known from other studies that a correlation exists between global rainfall and the incidence of meteor dust on the Earth, so the indictations now are for a considerable degree of climatic control by the Taurid-Arietid stream; and should there be confirmation of the strong concentrations of cosmic dust that have been detected in ice-core deposits corresponding to the last major glaciation (around 20,000 - 10,000 BP), and of their primitive meteoritic composition which seems to be identical to that of the Tunguska body, then powerful evidence is available of the way in which a particular giant comet, namely the most recent, has produced the last ice-age and continued to modulate the climate during the subsequent interglacial through the intermediary of stratospheric dust veils.

In essence then, we are learning from a considerable variety of indicators that a strong correlation exists between current properties of the astronomical environment and the Earth's history during the last 20,000 years: a giant comet has been the dominant controlling influence over the Earth's evolution during this period - we may note in passing

that the most recent mass extinction occurred only 12000 years ago during the last glaciation, apparently whilst a temporary climatic amelioration was in progress - and it is a process that simply represents in microcosm what has been going in continuously, albeit with the modulations tabulated above, throughout the Earth's history.

The provenance of ice-ages, particularly the most recent, has been a matter of contention amongst geologists for many years. Long before the Milankovitch hypothesis was developed (with its system of delicate feedbacks and hysteresis effects), there was a preference for dust particles in space determining the course of climatic change. No suspicion of the role of giant comets had appeared at this time but a prescient geologist has recently remarked that 'if a dust chronology were available, scientists could check it against the ice-age chronology'. This is certainly a pertinent comment for a time has now arrived where the wholesale retrocalculation of meteor orbits in the Taurid-Arietid stream is possible, and it may shortly enable us to identify the most significant fragmentations during the Holocene and correlate them with climatic variations and other terrestrial events. With the latter particularly in mind, we would also be in a position to examine the human record.

Thus, before 3000 BC, our ancestors would have regularly observed at least one large comet in the sky. It was probably a brilliant though essentially harmless spectacle, but also frequently an awesome one when orbital coincidences brought the Earth particularly close.

With a history of progressive splitting, one might expect several recognizable giants in similar orbits at this time, surviving for centuries or even a millenium. Such a family of gods in the sky, their eternal stream and the Earth's predictable and splendid encounters would enevitably generate a sense of lasting union between Heaven and Earth. At the epoch in question however, a major fragmentation of the primary body would produce an additional battery of comets and it would not be surprising if onlookers subsequently thought they were witnessing a battle for mastery over the sky, and that this was in some way associated with the assaults on the Earth that followed. These assults due to encounters with the core of the stream would in effect be global bombardments by Tunguska and super-Tunguska type bodies which would leave an indelible memory for the surviving humans and a lasting fear of the gods in the sky. We can well understand how a frenzied response might arise in the form of religious temples to propitiate the violent gods and astronomical observatories to anticipate future returns, though we have until now always assumed it was mere calendric or navigational requirements that arbitrarily inspired the growth of astronomy at this time, and mere technology that inspired a new generation to produce the pyramids and Stonehenge. With the passage of time, of course, the encounters would weaken and there would be only fireballs and declining comets to remind one of the former events, but at some stage there might always be a further fragmentation and a revival of the earlier terror. The scribes would scan the ancient records and attempt to prophecy the course of events but eventually

there would be no avoiding further multiple bombardment by Tunguskas and super-Tunguskas, with massive destruction of cities and the incineration of crops and land. Large scale migrations will take place as survivors seek to survive and doubts would be raised concerning the efficacy of prayer, a dark age would follow and a renaissance in due course with new questions about religion and cosmology. And then, with the passage of time, the whole process can be expected to repeat itself, continuing until the core of the giant comet has completely whittled away. We might even envisage destruction so great and dark ages so effective that only the dimmest memories will later exist of giants that once walked the Earth, of heavenly clouds that a creator once built in the sky, of prophets and messiahs who warned of doom and salvation, and of floods and cataracts of fire that were used to cleanse the Earth. We might then sympathise with an Aristotle, a Ptolemy or a Newton as they seek to dismiss the thunderbolts of a previous generation and restore a sense of order in Heaven and on Earth.

The peak of the observed fireball flux, superior to the present day's, coincided with the Taurid-Arietid stream according to European records a century or two after the time of Emperor Charlemagne and King Alfred. Indeed, whilst the latter fought to bring their peoples out of a deep dark age, Chinese rulers of the T'ang dynasty held astronomers under tight control, their duties being to prognosticate the future on the basis of signs in the sky such as meteors and comets. It was a period during which a remarkable wealth of brilliant fireballs was

recorded, and on one occasion for example, there was noted 'a great shower of meteors of all sizes, lasting through the night', and on another soon after 'dozens of small stars crisscrossing the sky through the night'. At the same era, on the other side of the Earth, the Anglo-Saxon Chronicle is being recorded and for the month of June 793 AD, it is noted that 'fierce, foreboding omens came over the land of Northumbria and wretchedly terrified the people. There were excessive whirlwinds, lightning storms and fiery dragons were seen flying in the sky. These signs were followed by great famine....' The very meagreness of the information available to us now may be a testimony to the destructive forces at play.

During the classical era too, we fail to understand the earliest natural philosophers and poets if we do not recognize their concern for the weapons and missiles brandished by the gods; meteorology was not then the wholly earthbound science that it has now become but the domain of astronomical agents who were only brought to the ground by Aristotle. Again we have many explicit statements by Chinese astronomers who warn us of the nature of the contemporary sky: "Dynasty Han, Reign Yuan-yan, Year 1, Month 4, Day Ding-you (ie 22 May, 12 B.C.). At the hour of rifu (ie 3-5 p.m.), the sky was cloudless. There was a rumbling like thunder. A meteor with a head as big as a fou (an earthenware pot), and a length of some ten-odd zhang (a zhang is 12 degrees), colour bright red and white, went southeastward from below the Sun. In all directions, meteors, some as large as basins, others as large as hens' eggs, brilliantly rained down. This only

ceased at evening twilight."

We cannot yet predict the future, the core body of the Taurid-Arietid stream has still to be observed. Indeed, the big guns of modern science are not trained in this direction at all. But there is a swarm of boulders out there and a future confrontation with a barrage of Tunguskas is a very reasonable projection from the state of current knowledge. At least one form of star wars can be virtually guaranteed and only time will tell whether it is an nuclear winter or a cometary winter that we face.

Notes and References

The suspicion that a conceptual error in physics leads to a misunderstanding of the nature of galaxies and hence of the origin and evolution of the Solar System has been raised in several papers (eg. S.V.M. Clube 1978 Vistas in Astronomy 22, 77; 1980 Monthly Notices of the Royal Astronomical Society 193, 385). The implicit new setting for terrestrial history in which giant comets prove to be the dominant evolutionary force has recently been reviewed by S.V.M. Clube and W.M. Napier in 1984 Monthly Notices of the Royal Astronomical Society 211, 953; 1985 "The Galaxy and the Solar System (University of Arizona, Tucson). The same authors presented a more popular exposition of this understanding of terrestrial catastrophism in "The Cosmic Serpent" (Universe 1982), in which they also discussed some of the possible implications for human history during the last 5000 years. Some indications of the nature of the problem in human history may be derived from Paul Hazard's "The European Mind 1680-1715" (Hollis and Carter 1953), Livio Stecchini's "The Newton Affair" (Kronos IX, 2, 34ff, 1984), F.M. Cornford's "Principium Sapientiae" (Peter Smith Publ.,Inc., 1971) and O.Neugebauer's" History of Ancient Astronomy: Problems and Methods" (1945).