

2 The Birth of the Solar System: Some Unconventional Ideas

The Two Conventional Alternatives

The formation of the Solar System has seen many attempted explanations. Back in the 1700s, three gentlemen independently arrived at the nebular hypothesis of the Solar System's genesis. They were philosopher-astronomer Immanuel Kant, Pierre-Simon Laplace and Emmanuel Swedenborg. The scenario as proposed by these thinkers begins with a vast, hot, slowly-rotating nebula or cloud of gas and dust. As this cloud rotates, the outer regions start to cool and, in the process of time, the nebula slowly contracts and spins up through the principle of the conservation of angular momentum. As the velocity of rotation increased, rings of material were ejected from the main body in a process that has been likened, rather inelegantly, to mud being thrown off the rim of a rapidly spinning wheel. Eventually, the rings break up into discrete clouds of gas and dust which, with the process of more time, condense into solid orbs; the planets. Meanwhile, the bulk of the nebula contracts into the massive central body which becomes the Sun (Figs. 2.1, 2.2, and 2.3).

This hypothesis did a good job of accounting for two major features of the Solar System. First, according to this scenario, all of the planets orbit in the same direction and their orbits remain close to the plane of the Sun's equator. It also follows from this hypothesis that the direction in which the planets orbit is the same as that in which the Sun rotates about its axis. Nevertheless, as it stands, the nebula hypothesis fails to explain why the observed speed of the Sun's rotation is so slow. If it formed from a contracting cloud,

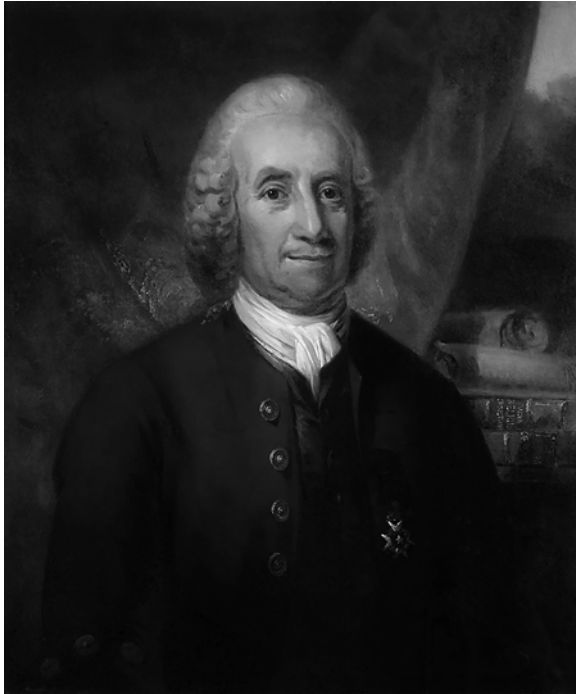


FIG. 2.1 Emmanuel Swedenborg (Portrait by Carl Frederik von Breda. *Courtesy: Wikimedia*)

it should have spun up dramatically (as the cloud was predicted to have done) from the conserving of angular momentum. As a ballerina spins faster as she folds her arms, contraction of any rotating mass must inevitably increase the velocity of rotation of that mass, unless it has some means of shedding its angular momentum. No such means appeared forthcoming to the early supporters of the nebular hypothesis.

Another difficulty encountered by the theory is the lack of an obvious reason as to why a nebulous cloud should start rotating in the first place. Why should it not simply float through space like one of our familiar clouds drifting through Earth's atmosphere?

In contrast to the uniformism of the nebular hypothesis, another early suggestion postulated a catastrophic scenario in which the planetary system was formed from the splash of solar material created by the impact of a large object crashing into the youthful Sun. Getting this ejected material to condense into



FIG. 2.2 Pierre Laplace (Portrait by Jean-Baptists Paulin Guerin. *Courtesy: Wikimedia*)

planets did not prove to be an easy task however, but what if the impacting object (which had to be another star, despite the initial speculation that it might have been a comet) did not actually impact the Sun at all? What if, instead, there was a narrow miss?

In 1901, Sir James Jeans proposed and developed just such a scenario and in so doing offered the first serious challenge to the nebular hypothesis. In Jeans' scenario, a second star passed extremely close to the Sun, almost grazing the latter's photosphere. Tremendous tidal effects were generated on both objects. According to Jeans, the tidal surge on the Sun rose in a huge "mountain" of gas as the second star approached and then "darted out as a long tongue of gas" which stretched far into space as a long filament, teased out in the direction of the departing star. The gravitational pull of the second star was not, however, sufficient to carry this filament along with it and the tongue of material,

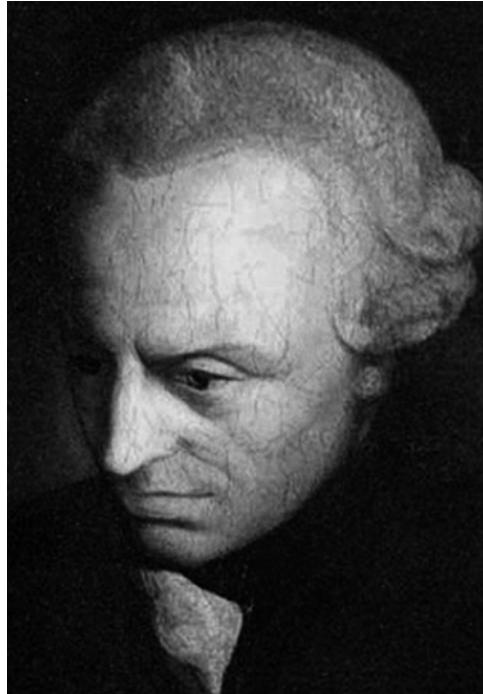


FIG. 2.3 Immanuel Kant (Portrait by unknown artist. *Courtesy: Wikimedia*)

though detached from the Sun, nevertheless remained within the latter's gravitational grip. The detailed theoretical investigation of the way in which such a filament would behave presents great mathematical difficulties, but Jeans conjectured that it might come to break up into a number of discrete condensations. The masses of these condensations are determined by the varying thickness of the original filament. Most of the filament's mass resided toward the mid sections, declining at either end. From this it follows that the more massive condensations will be the central ones, while those at each end of what we might picture as the cigar-shaped filament will be relatively small and lightweight. These condensations contracted to become the planets. As Jeans predicted, the truly massive ones—Jupiter and Saturn—inhabit the central regions while those at the sunward end were small by comparison, terminating in the diminutive Mercury at the very innermost tip of the filament. At the furthestmost tip,

Uranus and Neptune, though large when compared to Mercury or Earth, are nevertheless lightweights next to Jupiter and Saturn. Although Neptune marked the edge of the known Solar System at the time Jeans proposed this model, the discovery of the tiny Pluto in 1930 seemed to fit his theory very neatly. In short, the model proposed by Jeans appeared to predict the structure of the Solar System very nicely and also avoided the question left unanswered by the nebula hypothesis, namely, what started the hypothetical cloud rotating in the first place. Moreover, unlike the nebula hypothesis, it did not necessarily have a problem with the slow rotation of the Sun. Consequently, Jeans' theory became very popular amongst astronomers during the first half of the Twentieth Century. It is a little ironic that a catastrophist theory should have gained such wide acceptance at a time when uniformism reigned in most scientific disciplines, but that is surely a testimony to the theory's apparent capacity to account for the observed features of the planetary system (Fig. 2.4).



FIG. 2.4 Sir James Jeans (*Courtesy: uploaded to Wikimedia by Kokorik*)

Nevertheless, the Jeans model had some difficulties of its own. On the face of it, this model provided no reason why the orbital plane of the planets should be close to the equatorial plane of the Sun. Nor does it explain why the planets should orbit the Sun in the same direction as the latter's rotation. On top of this, there is the reluctance to accept a chance catastrophic event as an explanation unless all else fails (as it appears to have failed for the genesis of the Moon, for example). Moreover, the feeling that planetary systems are somehow "natural" consequences of star formation was further strengthened by the discovery of proto-planetary discs around many young stars, much as would be expected if the nebula hypothesis was, if not necessarily exactly correct, at least on the right track. Then, by the end of last century, the discovery of planets around other stars surely clinched the case for these being regular side effects of star formation and not the products of some freak type of event.

Currently, the most widely-held hypothesis of the Solar System's formation is a version of the nebula hypothesis, albeit with some important differences. Today, the Solar System is thought to have formed through the collapse of a small region of one of the giant molecular clouds that are scattered throughout the Galaxy. Just as in the model put forward by the Eighteenth Century pioneers, this region of the cloud collapsed under the influence of gravity, with the bulk of the mass contracting into the central regions to become the Sun. Planets formed from the surrounding cloud through the accretion of solid grains, first into pebbles, then boulders, then larger mini-worlds known as planetesimals and finally into the planets we see today. Nevertheless, the Solar System is a different and more complex place than Laplace, or even Jeans, imagined or even could have imagined given the data available at these earlier times. Partly through the discovery of other Solar Systems—most of which are a lot less sedate than our own—and partly through the continued study of our own system at both observational and theoretical levels, we now believe that the Solar System has passed through eras of turbulence beyond anything that Laplace and his contemporaries could have contemplated. Even on the model of Jeans, the System remained a relatively quiet and sedate place after it formed from

the filament left by that single, initial, catastrophe. Both Laplace and Jeans assumed that the planets formed pretty much where we see them today and both largely overlooked the presence of minor sub-planetary bodies as being of little consequence. The contemporary view of the Solar System is quite different. The early years were ones in which planets formed and migrated, some moving inward and others moving outward from their original places of birth. This migration was caused by their gravitational interaction with minor bodies; the remnant population of the vast numbers of planetesimals that did not snowball into major planets. Interaction between a planet and the myriad of planetesimals that it scattered every-which-way meant that it either gained or lost orbital momentum and consequently experienced either an expansion or a contraction of its orbit. Many of the planetesimals were either driven inward toward the Sun, flung out into interstellar space or pushed into large orbits far from the Sun. A good many of these objects were themselves large enough to be classified as dwarf planets and are still found to this very day orbiting in comparative obscurity out beyond Neptune. The strange little world Pluto—whose discovery appeared to boost the fortunes of Jeans' theory—is now known to be simply the closest, one of the largest and therefore (as seen from Earth) the brightest of these so-called Kuiper Belt objects.

Major planets also fell into orbital resonances with one another, meaning that relatively close approaches became established on a regular time scale, leading to drastic alteration of orbits over a longer lapse of time. Jupiter and Saturn were driven further apart and the "ice giants", Uranus and Neptune, relegated to large orbits far from the Sun. Previously, the presence of these two large planets so far out in space was seen by many as a problem for the nebula hypothesis. Simply put, there did not seem to be any way that sufficient material could be found so far from the Sun as to allow the formation of worlds as massive as Uranus and Neptune during the time taken by the formation of the Solar System. But given the "new" version of the hypothesis, with its mixture of uniformism and catastrophism (as we may fairly express it), this is no longer a problem. Uranus and Neptune actually formed much closer to the Sun where there *was* a sufficient supply of

planet-forming material, and were subsequently tossed out into the surrounding wilderness. One version of the theory indicates that Uranus and Neptune even swapped places as the most remote major planet, although at that time neither was as remote as it is today. For all we know, there may have been other planets that got ejected from the Sun's family altogether and are currently wandering around somewhere in the depths of the Galaxy.

The problem of the slow-rotating Sun has also been solved by this amended version of the nebula hypothesis. Gas also accompanied the collapsing system, but the gas did not orbit the young Sun as quickly as the accreting planets. This difference resulted in drag which transferred angular momentum from the Sun to the planets, in effect putting the brakes on the Sun and pushing the planetary orbits further out into space.

A study published in 2011 suggested that Jupiter migrated inward until it was just 1.5 AU from the Sun. According to this same study, after Saturn formed it likewise migrated inward, though not as far, establishing a 2:3 mean motion resonance with Jupiter. That is to say, it completed two revolutions of its orbit for every three by Jupiter. This situation had the effect of pushing both planets outward again until they reached their respective positions where we find them today. However, according to this scenario, Jupiter's sojourn in a relatively small solar orbit had the effect of scattering planetesimals in the region where Mars now resides and it is argued that it is due to this culling of the planetesimal population in that region that Mars ended up having such stunted growth. This particular hypothesis does not appear to have convinced many workers in the field and critics argue that the prevailing conditions within the inner Solar System at the time when this was supposed to have taken place were not likely to have been conducive to the migration of the pair of giant planets outward to their present orbits. Nevertheless, whether this particular version is right or wrong, it aptly demonstrates the sort of chaotic processes that formed the planetary system that we know today and, although not everyone working in this field agrees on all the details and several versions of the theory exist, most conclude that the general idea is essentially correct. Nothing too weird remains ... or does it?

But Is Gravity Enough?

Whether we look at the original nebula hypothesis, or its re-worked modern form, or even at Jeans' thesis, one common thread is seen to run through them all. The means by which the Solar System condenses from either a nebulous cloud or a filament ripped from the Sun, and the method by which the planets formed within that cloud or filament, is ultimately governed by a single force; gravity. On the face of it, there is nothing strange about this. Gravity is, after all, the dominant force on astronomical and cosmological scales. It may be nothing at atomic or molecular dimensions, but it reigns largely unchallenged when it comes to determining the structure and evolution of planetary systems.

Something that may easily be overlooked is the form that most of the visible matter in the universe takes. Unlike the material in our immediate terrestrial surroundings, much of the visible substance of the universe is not simply divided into the familiar states of solid, liquid and gas. On the contrary, the lion's share is in a fourth state; plasma. Not a great deal of this exists naturally on Earth, although we see it in such phenomena as ball lightning. But in the wider universe, the picture is very different. Plasma is defined in the Australian Pocket Oxford Dictionary as gas of positive ions and free electrons in about equal numbers. If we think about it for a moment, that describes just about everything from the stuff of stars to diffuse interstellar gas. In a very real sense, we live in a universe composed of plasma.

Well, so what? Plasma is still matter and it is still governed by gravitational force. True, but it is also far more susceptible to two other forces of nature—electricity and magnetism—than matter in the other three states. Is it possible that at least some of the tasks that we normally assume are carried out by gravity are really the work of electromagnetic forces governing the activity of plasma? There can be little doubt that electromagnetic plasma effects play some role, but a few scientists have developed the plasma scenario much further and worked out a model of the universe in which plasma not only dominates by its presence, but also determines the form taken by phenomena as diverse as galactic evolution and the formation of planetary systems.



FIG. 2.5 Hans Alfvén in 1942 (Courtesy: Wikimedia)

One such scientist—indeed the principal proponent of the plasma model—was Hannes Alfvén. Alfvén was well suited to be the champion of this theory. It would not be an exaggeration to say that he was the world's leading expert in plasma physics. He actually invented the field of magnetohydrodynamics (mercifully referred to as MHD), for which he was awarded the 1970 Nobel Prize (Fig. 2.5).

A short critical account of Alfvén's broader cosmological theory was already given in *Weird Universe*, so a brief summary will suffice here to place his views on the genesis of the Solar System within their wider perspective.

Alfvén's early ideas on the subject of plasma cosmology were published in his 1966 book *Worlds-Antiworlds*, and further developed in 1971 by his colleague O. Klein into what has come to be known as, either, the Alfvén-Klein or the Klein-Alfvén cosmology.

These authors begin by noting the puzzling observation that, although experiments using particle accelerators always produce particles and anti-particles in equal quantity, the universe at large contains very little anti-matter. This is usually explained by assuming that the creation process favored one form of matter or that a slight asymmetry in the amounts of matter and anti-matter exist (albeit too small to be detected in particle accelerator

experiments) and, as Einstein remarked "matter won". The third way around the problem is the suggestion that matter was never created; that it has eternally existed. That may have seemed an option once, but it now flies in the face of just about everything we know of the universe and is not even worthy of serious consideration in the opinion of most contemporary cosmologists.

Alfven and Klein opted for yet another way out of the problem. They simply accepted what the particle accelerator observations revealed. Matter and anti-matter do indeed exist in equal quantities in the universe, but they are kept apart by cosmic electromagnetic fields formed between two thin boundary regions consisting of two parallel layers displaying opposite electric charges. Interaction between these boundary regions generates radiation, which in turn ionizes gas into plasma. Both matter and anti-matter particles are ionized in this way, resulting in a mixed plasma to which Alfven gave the name ambiplasma. The boundary layers are therefore formed of this strange matter/anti-matter substance. Although we might think that the matter and antimatter components of the ambiplasma should explosively annihilate one another upon contact, Alfven argues that because the particles and anti-particles composing it are too energetic and the overall density of the ambiplasma too low to allow rapid mutual annihilation, the ambiplasma should in reality be quite long-lasting. Moreover, the double layers will on the one hand act to repel clouds of particles of the opposite type while on the other hand attracting and combining clouds of particles of the same type. The upshot of this is a segregation of matter and anti-matter particles into ever-larger concentrations.

With a few minor exceptions, we only see matter simply because our region of the universe just happens to lie in one of the positive regions. But at great distances, beyond those accessible to our telescopes, this matter region gives way to an anti-matter region and because there is a slow annihilation of the matter/anti-matter particles along the boundary between these regions, the material within our visible universe slowly drifts outward. According to Alfven, it is this drift that we detect as the cosmological redshift of galaxies and mistake for the expansion of space. The Big Bang, Alfven opined, did not take place. Not at least, as the beginning of anything of fundamental cosmological significance. There may have been *a* big bang, but if there was, it was just one of

the many violent events that take place from time to time in the universe. The universe itself, in the opinion of Alfven, had neither beginning nor end as far as can be ascertained.

As a cosmological hypothesis, this scenario encounters increasing difficulties as more details about the universe-at-large come to light. But Alfven does not confine the plasma hypothesis to this broad cosmological model. He sees evidence of plasma wherever he looks in the universe. The morphology of galaxies can be explained by understanding these as contracting balls of plasma. Much of what happens within the galaxies is also plasma related in his view; including the formation of Solar Systems like and, of course, including, our own.

Alfven voiced his dissatisfaction with what we might call traditional theories of Solar System formation in his Nobel lecture of December 11, 1970. He criticized the contemporary theories in so far as he saw them as essentially theories of the history of the Sun. Drawing comparison between the Solar System and the satellite systems of the giant planets, Alfven expressed the opinion that what should be developed is "a general theory of the formation of secondary bodies around a central body." The Solar System would then be seen as one application of this wider general theory. Not surprisingly, he saw this general theory as dealing with the evolution over time of a body of plasma.

The sequence of events through which all of the situations covered by the proposed general theory would pass can be summarized thus: "A primeval plasma was concentrated in certain regions around a central body and condensed to small solid grains [some of which may even have been present in the first place]. The grains accreted to what have been called embryos and by further accretion larger bodies were formed." Depending upon the specific application of this general scenario, these larger bodies may either be planets orbiting a star such as the Sun or moons orbiting large planets like Jupiter or Saturn.

Traditionally all of this is seen as the work of gravity, however Alfven reasoned that simply because the contracting mass is a plasma, other influences must come to bear upon the final outcome. In this, Alfven was resurrecting an idea that had previously been suggested by Arrhenius, whom we met in the previous chapter during our discussion of panspermia. What we actually

have, according to Alfven and Arrhenius, is a mass of gas infalling toward a spinning central magnetized body while being ionized (i.e. turned into plasma) and brought into partial corotation with that central body. Grains condense from this plasma and, losing their electric charge, fall toward the equatorial plane where they are collected at various discrete distances from the central body. Sticking together, the grains first of all form streams of almost co-orbital particles to which Alfven gave the name of "jet streams". Within these jet streams, the grains continue to snowball together into larger and larger bodies. These are the planetesimals which, gently colliding and sticking together, form the final orbiting objects; be these planets orbiting a star or satellites in orbit around a large planet. Gravity becomes paramount only during the final stages of this accretion process.

Although this process, as applied to the formation of the major planets of the Solar System and principal satellites of the giant planets, was completed long ago, Alfven argued that minor examples of this form of accretion are found to this very day not too distant from our home planet. In a curious reversal of the accepted wisdom on such matters, Alfven and A. Mendis proposed, in the early 1970s, a scenario in which meteor streams become, as they expressed it, the source as well as the sink of comets and Apollo asteroids. In other words, they argued that the particles within meteoroid streams accrete together in the manner just described to form small planetesimals, completely or partially formed instances of which constitute the comets or asteroids generally designated as the parent bodies of such streams. Rather than being the parents of meteor streams via a process of gradual breakup and decay, these objects are seen by Alfven and Mendis as the children being born through the steady snowballing together of the meteoroids themselves.

Of course, both authors admit that there are instances where the existence of a meteor stream is clearly due to the breaking up of a parent body. The well-known instance of Comet Biela and the Andromedid meteor storms can hardly be explained any other way. This is, in other words, a clear case of the meteor shower being the sink.

Yet, referring to an earlier study by J. Trulson, Alfven and Mendis also argued that a stream of meteoroids might just as well act as the source of a small Solar System object. Following Trulson,

they proposed that a meteor stream (understood as an example of a jet stream in the Alfvén sense) that approaches Jupiter closely enough to be affected but not so closely as to be totally disrupted, can experience a velocity modulation of its constituent particles in a way that results in the creation of a travelling density wave. In itself, that will have no great and lasting consequence, however if the stream experiences two consecutive encounters with Jupiter, and two density waves are generated, it is possible for these two waves to interfere with one another in such a way as to create a region of significantly greater compression within the stream. Furthermore, if an appreciable amount of gas remains in the jet stream, we could no doubt add viscous effects into the mix as well and an even more enduring concentration could, in theory, occur. Denser concentrations of this type may condense still further on quite short timescales into something not too unlike a primitive planetesimal; either a comet or an Apollo asteroid. Alfvén calculates that the entire process may complete itself on a timescale of just 90,000 years or thereabouts; a mere blink of the eye compared with the age of the Solar System.

Because they possess a rather large cross section, meteor streams are seen by these authors as a rather efficient means of mopping up interplanetary grains that were not originally members of the streams themselves. Because some of these grains, in regions of the Solar System more or less remote from the Sun, might be expected to contain water ice and frozen gases, some of the newly accreted bodies will contain volatiles and be capable of cometary activity while other grains originally orbiting at smaller distances from the Sun will be dry and the bodies forming from them will be inert asteroids.

The authors present as evidence favoring the recent formation of objects from meteor streams, the apparent late discovery of the so-called parent comets of two of the most famous of these streams; the Perseids and Leonids. Both of these showers have been known for centuries; references to them having been found in ancient Oriental records. Yet, according to Alfvén and Mendis, their accompanying comets were only discovered during the nineteenth century. They remark that, if this conclusion is correct, the accretion of these objects from their associated meteor streams

constitutes a "cosmic laboratory where we could still observe though on a much diminished scale the planetesimal process which led to the formation of the Solar System over 4.5 million (sic) years ago." (*Study of Comets* Part 2, p. 657).

Unfortunately for those wishing to see a scaled down version of this process, the late discovery of the two comets cited by these authors does not mean that they only formed during the last couple of centuries. The Leonid comet (55P/Tempel-Tuttle) is an intrinsically rather faint one which only makes naked-eye visibility during a very close approach to Earth. Close approached did, however, take place in 1699 and earlier in 1366 and on each occasion a fast-moving comet was observed. Orbital computations have identified each of these with Tempel-Tuttle. The Perseid comet (109P/Swift-Tuttle) is, by contrast, intrinsically rather bright, but is frequently badly placed and, having a period of around 130 years, is not a frequent visitor to our skies. Nevertheless, it has now been identified on a small number of occasions in ancient records; the first of these being over 2000 years ago.

The Alfven-Mendis model has not won many followers, to put it mildly. Despite the theoretical possibility of concentrations in meteor streams arising from the interference of density waves, the process seems an unlikely one to occur in nature with the required intensity to produce the results that the theory demands. Meteor streams are very diffuse and the prospect of such snowballing seems rather remote. The masses of some of the associated objects would also demand that their streams contained a great deal of material in their youth. Comet Swift-Tuttle, for example, appears to be very large with estimates of its nucleus as high as 30 km (18.6 miles) in diameter. A great number of meteoroids are also required to build a decent sized Apollo asteroid. Moreover, the requirement of gas being present in the streams has no observational justification and seems unlikely at best. On the other hand, the process of steady disintegration of comets and some asteroids has both observational and theoretical bases and we have clear evidence (as already mentioned and as admitted by Alfven and Mendis) that at least some meteor streams arise from this process. Without strong evidence to the contrary, there seems no compelling reason not to believe that all of them have a similar genesis.

Planets Spun from the Sun?

Although the plasma theory of Alfven and colleagues differs in certain respects from what has become the widely accepted form of the nebular hypothesis, it is still broadly within the bounds of that scenario. Like the orthodox model, it sees the planetary system as accreting from a cloud of material surrounding the infant Sun.

Nevertheless, despite the theoretical and observational support for this thesis, a few dissenters remain. One of these was the very controversial Thomas Van Flandern to whose hypothesis we shall now turn (Fig. 2.6).

Basically, Van Flandern objected to the dependence that all forms of the nebular hypothesis placed upon particles colliding and sticking. He writes "At first, the sticking results in pairs of molecules here and there. Eventually, some of these collide with each other and stick, and bodies of larger and larger size ultimately are build up ... the literature supposes that high velocity collisions are destructive, whereas low-velocity collisions are 'constructive' i.e., result in sticking" (*Dark Matter Missing Planets & New Comets*, p. 328). He admits that small bodies that collide with larger ones



FIG. 2.6 Thomas Van Flandern (Courtesy: American Astronomical Society)

will tend to accrete there, but is mystified why gently-colliding objects of approximately equal mass should “stick” together. He doubted that the relative velocity of the particles would be low enough and wondered where the supposed “stickiness” was supposed to originate. Once larger bodies are involved, gravitational attraction takes over the accretion process, but the initial problem (as Van Flandern saw it) is how the process is able to reach that rather late “gravitational” stage at all.

Nevertheless, even this later stage of accretion encounters problems in explaining the growth of planets in nearly circular orbits around the Sun as well as moons in similar orbits around their primary planets. Accretion through gravity works but, Van Flandern argues, only if the orbits of the accreting bodies are mildly chaotic. In the case of circular orbits, objects sharing the orbit of a larger body are forced to librate back and forth and thereby avoid collision with the larger mass.

Van Flandern also raises the old problem of the slow-rotating Sun as well as pointing to the difficulty of planets as distant as Neptune accreting from what must have been very diffuse material so far from the central hub of the Solar System. Both of these apparent difficulties now look a lot less daunting since the time of Van Flandern’s writing, thanks to the further development of the nebula hypothesis.

Finally, Van Flandern points to the similarity in chemical composition of Solar System objects as evidence that they formed under a smaller range of temperatures than the nebula hypothesis required. Specifically, he noted the presence of abundant carbon dioxide on the surface of Neptune’s moon Triton, arguing that this is very difficult to explain if this body had formed in situ and had in consequence never been much warmer than it is at present. Once again however, more recent models of the early Solar System allow for a good deal of mixing of materials, so that it is not surprising to find high-temperature and low-temperature species together in the same object, as evidenced by analysis of dust collected by the *STARDUST* probe from the coma of Comet Wild 2. Also, the acceptance of the phenomenon of migration of planets means that we are no longer tied to the assumption (one could rightly say presumption) that Solar System objects have always been where we see them today. Quite the contrary, in fact.

Van Flandern does not claim to present a fully worked out Solar System model of his own, but he does provide an outline of the form which he believes that such a model would assume.

Broadly speaking, he apparently agrees that the early Sun formed from a contracting cloud of matter. Through the conservation of angular momentum, the proto-Sun must, he argues, "reach an overspin condition numerous times during its contraction phase." (*DM*, p. 331). Each time this happened, a blob of matter would be thrown off, taking with it some of the proto-Sun's angular momentum, and thereby causing its spin to decrease to below the critical velocity. Yet, because the proto-Sun continues to contract throughout this process, it will not be long before conservation of angular momentum again spins it up to critical velocity and the process begins all over again; another blob is ejected and some more angular momentum is lost. Eventually, the proto-Sun settles into its stable state and is no longer "proto". What eventuates now is a young star surrounded by blobs of matter thrown off at points where its rotational velocity had become critical. Tidal forces would, Van Flandern argues, act on these orbiting blobs in such a way as to enlarge their orbits. Moreover, the blobs of material would start out with the forward spin of the proto-Sun and must therefore all be rotating in the same direction, something which the nebular hypothesis does not readily explain in Van Flandern's opinion. Moreover, each would go through the same sort of contraction and fission process experienced by the proto-Sun, albeit on a much reduced scale. In time, the blobs of material thrown off by the contracting proto-Sun would become the major planets, complete with their systems of satellites.

Van Flandern admits that the notion of planets being spun off the Sun had previously been presented and rejected on the grounds that the present rate of rotation of the Sun is well below the critical level, plus the observation that the Sun's equator does not quite lie in the plane of the planetary orbits, being just 7° off the mean plane of the planetary system. These objections do not worry him however. He suggests that both conditions can easily arise if the interior of our star spins much faster than its surface and if the tilt of the Sun's spin axis was altered during the contraction phase by interactions between the faster-spinning core and the slower-spinning outer regions. Van Flandern considered

that the evidence available at the time of his writing (concerning the differential rotation rates between the solar surface at the equator and at the poles) pointed to a rapidly-rotating solar interior. Later research has not, however, confirmed this. The outer regions of the Sun rotate fastest at the equator and slowest at the poles and this pattern continues throughout the convective zone within the Sun's interior. However, the situation changes at the boundary between the convective and radiative zones, known as the Tachocline. This boundary is situated at one third of the solar radius. Rotation changes, at the Tachocline, to a solid-body form and continues in this form throughout the radiative zone, right to the Sun's center. The rate of this solid-body rotation is about equal to that of the surface at middle latitudes—intermediate between the fast equatorial and the slow polar values.

In view of these findings, the rotation of the Sun remains a serious problem for Van Flandern's hypothesis. Moreover, as mentioned earlier, more recent discoveries of pre-planetary nebula surrounding other stars and the evidence that planets are accreting within some of these in the manner postulated by the nebula hypothesis seems to supply direct observational evidence that this process actually works in nature. Planetary migration adds a further complicating feature. While this process is included in Van Flandern's model to a certain degree, the outward expansion of orbits such as he envisions is very mild fare when compared with what is now thought to take place during the early ages of planetary systems. Our own system must have been truly chaotic, yet it pales in comparison to what must have taken place in some (possibly most) other planetary systems in the universe. But that is a good thing for us. Had the Solar System gone through what most of the newly discovered systems experienced, we most probably would not be here at all.

Exploding Planets

For the present however, we will overlook the difficulties inherent in Van Flandern's general model of the Solar System and take a look at some specifics. This is where we find that Van Flandern's Solar System was not only formed in a manner differing from the

more widely held models, but also had some physical differences from the system that any of these other models predicted.

The early Solar System, according to Van Flandern consisted of Venus and its moon (which eventually broke away to become the planet Mercury), Earth, Planet V, Planet K, Jupiter, Saturn, Uranus, Neptune and their various moons; one of Neptune's eventually escaping to become Pluto. Our own moon and what is now the planet Mercury each formed from their respective parent planets by fission and what we now call Mars formed in a similar manner from either Planet V (orbiting roughly where Mars is today) or Planet K which supposedly was a superterrestrial of between 5 and 20 Earth masses that orbited at a solar distance of around 2.8 AU; roughly in the middle of today's asteroid belt, close to the orbit now occupied by the dwarf planet Ceres.

Now what, we may ask, became of the planets designated as V and K? This is where things get truly weird—according to Van Flandern, both of these worlds exploded.

The idea of an exploded, or at least shattered, planet goes back to H. Olbers in the early Nineteenth Century. This was the time when the first asteroids were discovered and Olbers put forward the quite reasonable-sounding hypothesis that such objects were the remnants of a planet that once orbited between Mars and Jupiter but that had for some reason broken apart in a truly catastrophic event. The idea went out of fashion in favor of the less catastrophic idea that the small bodies within that region were essentially partially formed planetesimals that were prevented from coming together to form a true planet because of the disrupting effect of the gravitational tug of giant Jupiter. Vestiges of the Olbers approach were resuscitated however as the explanation for groups or families of asteroids sharing very similar orbits around the Sun; the so-called Hirayama families, named in honor of Kiyotsugu Hirayama who discovered them in 1918. Most of these groupings are believed to have arisen from the breaking up of larger parent asteroids, most probably following collision with other bodies within the main asteroid belt, although groupings of smaller objects might also arise from the rotational instability of rapidly spinning asteroids.

Nevertheless, in the 1970s, Canadian astronomer M. Ovenden revived the original broken planet model. He harked back to the

1814 development of Olbers' hypothesis by J.L. Lagrange which supposed that both asteroids and comets were the remnants of the hypothetical disintegrated planet. According to Ovenden, the planet not merely disintegrated but exploded with such violence that its debris was scattered all over the Solar System; some the rocky material going into sedate orbits in the asteroid belt while much of the outer layers got hurled to the farthest reaches; much of it leaving the Solar System altogether. The fragments that did not quite go careering off into interstellar space are returning today as long-period comets. By the way, the name given by Ovenden to his hypothetical exploding planet was Krypton, not implying that it was filled with the inert gas of that name, but in honor of the mythical home planet of the comic-book character Superman and which, according to the story, suffered a similar fate. This is why Van Flandern calls his second exploding planet "Planet K"—second because he also argued that Planet V blew up at an earlier date in the Solar System's lifetime. The demise of Planet K was, however, a very recent event in terms of Solar System history. According to Van Flandern, it happened only around three million years ago.

The main support for the exploded planet hypothesis, in Van Flandern's opinion, is the existence of the asteroid belt itself. He argues that bodies even as small as the average asteroid could not have accreted in their contemporary position if the Solar System of ancient times had been much the same as we see it today. Each exploded planet contributed to the asteroid population of the Solar System. The innermost of the two, Planet V, was named as the parent of S-type asteroids; dry, rocky bodies from which ordinary chondritic meteorites are almost certainly derive. Planet K gave us C-Type asteroids, the most common objects in the outer regions of the asteroid belt and the ones believed to have very similar composition to carbonaceous meteorites.

Van Flandern also sees evidence of the explosion in the nature of the orbits of asteroids and comets. Looking first at the orbits of asteroids within the so-called main belt between Mars and Jupiter, Van Flandern admits that some of the original explosion signatures of these would have disappeared. For instance, although all the orbits must originally have passed through the point in space that the planet occupied at the time it exploded, precession would have long ago eliminated this common point.

Nevertheless, several patterns would continue to be present. For example, there would be a "minimum eccentricity ... for every mean distance from the Sun" (*DM*, p. 186). Orbits at the mean solar distance of the point of explosion would be circular, while those with smaller or greater distance "must have at least enough eccentricity at some time that they can reach the mean distance of the explosion." Such evidence does, he claims, exist. Although some of the S-type asteroids in the inner regions of the main belt do not conform to the prediction (a discrepancy which he suggests might be explained by these objects being collisionally evolved) there is, he argues, a trend found within the orbital eccentricity of main-belt asteroids such that "the further their mean solar distance is from 2.8 AU, the greater is the minimum eccentricity of all the orbits found at that mean distance" (*DM*, p. 186).

But orbital evidence favoring a planetary explosion is not, he argues, confined to the asteroid belt. Indeed, if the explosion occurred about three million years ago and if it ejected fragments almost to the escape velocity of the Solar System, these fragments should now be returning to roughly the point of their explosive birth on elliptical orbits having periods of around three million years, give or take a fair amount of scatter due to stellar perturbations and the like. Dynamical studies of first-time or dynamically new comets do indeed indicate periods of this order and Van Flandern sees this as evidence supporting his exploding planet thesis. However, an object coming into the central planetary system from a distance close to the maximum for something still gravitationally bound to the Sun will naturally have periods of this order irrespective of whether that object began life as a piece of planetary shrapnel shot out at just under escape velocity three million years ago or whether it experienced gravitational acceleration to near escape velocity billions of years ago and has ever since been parked in a precarious orbit about as far from the Sun as it could go without drifting off into the interstellar void. The latter scenario developed from the one put forward by J. Oort and which is widely accepted today. As it stands, the appeal to the periods of these dynamically new objects alone does not decide whether Oort or Van Flandern is correct.

It is only fair to remark however, that Van Flandern's concept of the Oort Cloud understands its supporters as hypothesizing that

this great sphere of distant objects condensed in situ from the outermost fringes of the contracting pre-solar nebula. That seems to have been the opinion of E. Opik, who came to the distant comet reservoir conclusion independently of (and actually prior to) Oort. At least, he mentioned this genesis of the Oort Cloud as a possibility although he did not work it out in detail. Van Flandern is rightly critical of this version of the hypothesis, pointing out that at the distances being discussed, matter would have been so thinly distributed that accretion into solid bodies of any size could not have taken place. Nevertheless, Oort was in complete agreement with Van Flandern as to the impossibility of comets forming at the distances he postulated. He saw the formation of these objects as a natural consequence of planetary accretion and one that took place relatively close to the infant Sun, in the same region where the planets themselves formed. In his scenario, the accretion of comets represented a stage in planetary formation. Most of the comets snowballed into the planets themselves, with much of the remainder being gravitationally expelled from the Solar System. Those eventually taking residence in the Oort Cloud were the ones that escaped assimilation into planets but were ejected at velocities not quite reaching that of the escape velocity of the Solar System. This picture is, broadly speaking, the one most widely accepted today. In so far as it depends upon ejection from the region of the planets, certain similarities may be drawn between it and Van Flandern's model, while noting that the ejection took place during the period of planetary formation over four billion years ago and, even then, was not a consequence of a planetary explosion.

Van Flandern also draws attention to another aspect of the dynamics of these dynamically new comets which he claims supports his hypothesis. He reminds his readers that "If comets did originate in a breakup event in the inner Solar System, then the original distance of closest approach to the Sun ... for their orbits must all have been less than or equal to the distance at which the breakup occurred." (*DM*, p. 189). From this, he predicts that "there will be fewer comets with perihelion points inside the Earth's orbit than for a comparable range outside the earth's orbit" and finds that this is indeed reflected in their orbital statistics. Nevertheless, to prove the prediction made in the first of these quotes, those same orbital statistics should also reveal a marked

decline in the numbers of comets coming to perihelion at distances greater than about 2.8 AU, where Planet K was supposed to have been located. Early statistics may indeed have appeared to support this, but only because comets at large distances will inevitably be faint objects, except for the very few of unusually large size and high intrinsic brightness. Thanks to the deep searches of the past couple of decades however, comets with perihelia out past 9 AU are being picked up and we can be sure that even now most of the fainter ones are passing by unseen. There is clearly no falling away of numbers once 2.8 AU is passed. Furthermore, the number passing within Earth's orbit does not appear especially small for this volume of space and some have been observed to come very close to the Sun itself. The closest approach on record for a comet that can definitely be identified as having come straight in from the Oort Cloud was made by Comet ISON in late 2013. This rather small object approached the Sun to just 0.01 AU and was reduced to a cloud of dust for its impertinence.

Van Flandern's theory of comets does not stop with his account of their origin. Not surprisingly, his model of the physical nature of these objects also differs in some important respects from the one widely held today, but more about this in Chapter Four of this book.

Following the planetary explosion, according to Van Flandern, a cloud of dark carbonaceous material spread throughout the Solar System and dusted the planets to a greater or lesser degree. Objects having a slow rotation were most conspicuously affected by this cosmic dust storm. One body which Van Flandern sees as having been especially marked by this event was Saturn's moon Iapetus. This is the moon with one relatively bright and one unusually dark hemisphere and it is easy to understand why such a discrepancy of surface albedo should have been especially interesting to Van Flandern. Nevertheless, the explanation for the two-faced character of this object appears more straightforward than he opined. The presence of Saturn's dark-surfaced moon Phoebe is generally thought to be the culprit. Dark carbonaceous dust particles ejected from the surface of this moon appear quite capable of explaining this odd characteristic of Iapetus. Phoebe orbits Saturn beyond Iapetus and travels in a retrograde direction. Particles ejected from its surface likewise follow its retrograde path and, as Iapetus

pursues its prograde orbit around the planet, these are swept up by its leading hemisphere. Nevertheless, the full explanation of the dark hemisphere of this moon does not stop there. Because the material from Phoebe is so dark, it absorbs more energy from the distant Sun than the surrounding, icy, surface of Iapetus, causing the dark region to become warmer than the surrounding areas. In the warmer micro-environment, volatile substances evaporate, leaving behind dark material native to Iapetus itself and darkening the region still further. This in turn increases the absorption of solar energy and so on, with the upshot being the evaporation of ices from the dark hemisphere and their recondensation on the bright one, leading to the extreme contrast that we see today.

Evidence for this model has been observed in the form of a ring of dark dust particles in the orbit of Phoebe, presumably composed of particles that have recently been ejected from the surface of this moon. The reason for this ejection of particles is widely thought to be due to the impact of meteoroids, however there is another possibility which the present writer has raised from time to time. Almost certainly, Phoebe is not a native moon of Saturn. It is thought to have once been a free-orbiting body that was captured by the giant planet's gravity, as evidenced by its retrograde orbit and large distance from Saturn itself. In all probability, it was once a centaur similar to Chiron. These objects appear to be large comets and activity has actually been observed on some of them, including Chiron itself. It does not seem unreasonable to think that Phoebe may have experienced periods of cometary activity, maybe triggered by a meteorite strike cracking away an area of insulating surface crust and exposing a fresh reservoir of frozen gases. Maybe the dark ring and the black face of Iapetus were caused by dust ejected during one or more such episodes. Nevertheless, whether raised by meteoroid impacts or by cometary activity on Phoebe, it is clear that the dust coating the leading hemisphere of Iapetus can be explained more simply than by involving the presence of an exploding planet.

Such difficulties with the model as those cited above pale in comparison with the deeper problems that it raises. In the opinion of the present writer, the type of recent catastrophic event envisioned by Van Flandern has two overriding difficulties. First, why should a planet, formed billions of years earlier, suddenly explode

and, secondly, what effects would such an extreme event have on the nearby worlds in the Solar System?

Looking at these in reverse order, it seems to me that something as dramatic as Van Flandern postulated would have greater effect than a few impact craters and a dark coating on one side of a Saturnian moon. The sort of event he pictured is demonstrated by the opening paragraphs of his chapter on the topic of planetary explosions in *Dark Matter*. He begins with an account of the eruption of Nova Cygni 1975! Unfortunately, his treatment of the nature of this event could be confusing for today's reader as the process he describes is really that of a core-collapse supernova and his remark that the Sun will end this way in the very distant future is no longer believed to be the case. This just means that the interpretation of novae has moved on in recent years and it is now recognized that these are not single stars that for some reason blow up but are members of an especially violent category of what are known as cataclysmic variables. These objects involve a pair of stars in close orbit around a common center of gravity. Both stars are very old and have departed from the hydrogen-burning main sequence but one of them (presumably the more massive of the pair during its main sequence sojourn) has already gone through the stage where its core has collapsed into an ultra dense degenerate state—a white dwarf as these degenerate cores are called—and the outer layers have been puffed off into a planetary nebula. This, it is now believed, is what will happen to our Sun billions of years from now. The other member of the pair has only aged to the red giant stage. That is to say, it has swelled out enormously into a distended and relatively cool envelope. Stars pass through this stage prior to the white dwarf/planetary nebula phase and smaller stars take more time to reach it than larger ones (very small and very large ones have different destinies entirely, but that is another story). Cataclysmic variables occur when the white dwarf pulls material away from the distended red giant. This material spirals down onto the white dwarf and collects on its surface, building up until a critical mass is reached and the layer of accreted material goes off like a thermonuclear bomb on steroids! Neither star is any the worse for the explosion. Indeed, it acts as a safety valve for the white dwarf. Sometimes, for reasons not yet clear, the explosion does not occur as described above and so much material is collected that the entire white dwarf is converted into an exploding bomb; an inconceivably violent event

known technically as a Type 1 supernova. In the milder classical novae however, the glowing gases in the explosion's aftermath may outshine the combined light of both stars by anything from a few hundred to a million times for a relatively brief period of time. Nevertheless, the system soon settles down and the accretion process begins all over again, ready for the next time.

This picture of a nova, although given briefly and oversimplified here, is pretty much established through detailed observations. They are not really exploding stars and no nova ever observed hints at having been an exploding planet; which is just what Van Flandern suggested. In other words, according to his hypothesis, if an alien civilization in a neighboring planetary system happened to be looking skyward around three million years ago, they would have seen a nova near a yellow star which we now call the Sun. They would have seen something similar to what we earthlings witnessed in 1975.

Think about this for a moment. Early hominids walked the Earth in those days. What effect would a second Sun, far and away outshining the first, have had on them? What effect would the blast of radiation have had on life in general? While there is no detailed assessment of the effects of a nova within the Solar System, but it seems intuitively obvious that surface life on Earth would have been wiped out and, most probably, the planet's atmosphere and oceans dispersed into space as well.

Then there is the vexed question as to why a planet should explode in the first place. Nothing we know about the internal constitution of planets leads us to suppose that they are prone to blowing up; which is good news in view of the fact that we live on one of them. A definitive answer is not given by Van Flandern, although he does make several suggestions, some marginally more plausible than others. On page 163 of *Dark Matter*, he writes "we have only recently learned that thermonuclear processes similar to those in a star may now be taking place in the core of the planet Jupiter, which emits more heat than it takes in from the Sun." A similar remark was once made by the equally controversial V.A. Firsoff, who speculated that deuterium fusion might be occurring within the core of Jupiter. It is true that deuterium fusion does take place in objects that are similar to Jupiter in composition, however we now know that the mass of even that giant planet is insufficient for this reaction to have started up in its core.

The heat that this giant planet emits is a product of its steady contraction. Giant Jupiter is getting smaller, albeit by only about 2 cm (not quite 1 in.) every year. Still, this contraction is enough to heat the core of the planet to something like 36,000°; hot indeed, yet still too cool to trigger thermonuclear reactions.

In order to reach the temperatures and pressures required for deuterium fusion to begin, Jupiter would need to be some thirteen times more massive than it is. It would then be classified, not as a planet but as the smallest and most lightweight form of brown dwarf; one of those transition objects that fill the gap between massive planets and lightweight true stars. Increase the mass of Jupiter to 65 times its present value and lithium would also start fusing in its core, transferring into the class of more massive brown dwarfs. A further increase to 75 times its real mass would enable hydrogen to fuse and it would finally graduate into the class of true stars, albeit only to become one of the smallest of the faintest members of the category of so-called red dwarfs. Yet, even if (counterfactually) conditions within the core of Jupiter did allow atomic fusion to take place, there is no reason to expect that it would explode. We don't see brown dwarfs or red dwarfs exploding. In fact, we have no reason whatsoever to believe that such events occur. Furthermore, Jupiter did not explode. Van Flandern's hypothetical exploding planets were much less massive than Jupiter, so what happens—or fails to happen—within the core of this planet has no relevance to the supposed demise of Planets V and K.

But if fusion reactions cannot perform the required task of blowing a planet to smithereens, perhaps fission can work. Van Flandern raises the speculation that natural fission reactors—concentrations of radioactive materials deep within planets—might sometimes reach critical mass and, in effect, turn into naturally occurring atomic bombs on a truly gargantuan scale. Considering the comparatively rare nature of sufficiently radioactive materials, this seems rather farfetched to put it mildly, although the question of possible natural reactors or even atomic explosions on a small scale has been raised by other researchers in association with some geological features. Van Flandern points to evidence of natural chain reactions in Gabon. Such reactions cannot happen today because of the depletion over time of U-235, but around 1800 million years ago there was four times the amount of this isotope and chain reactions were possible. The chance that these could blow up an entire planet, however,

seems pretty farfetched and that suggestion would require a lot more evidence before it is taken seriously. Moreover, the planetary explosion in which Van Flandern is most interested is supposed to have taken place just three million years ago, not nearly 2000 million.

Van Flandern's next speculation comes very much from the proverbial left field. He points to the discovery of high energy gamma rays from the galactic center and notes that the energy of these (511,000 eV; an enormous energy in comparison with the feeble 2 eV of visible light, as Van Flandern is quick to point out!) is just what would be expected to issue from the annihilation of 10^{10} tons of positrons (anti-electrons) every second. He further notes that gamma rays having the fantastic energy of 1.8×10^6 eV have also been detected coming from the galactic center and sees this as evidence that several stellar masses of the short-lives radioactive element Aluminum 26 is continually decaying there. The production of this element is usually associated with supernova explosions, but Van Flandern suggests an association with the positron annihilation taking place at about the same location. He then states that "Al 26 is also found in carbonaceous meteorites" (*DM*, p. 164), which in his opinion represent part of the debris from the exploded planet, and from this he draws the tentative conclusion that "the suggestion is clear that antimatter might have played a role in the explosion of the missing planet too. Although clearly no detailed mechanism can yet be proposed, the same lack of a detailed mechanism is true about the galactic center". From this tenuous position, he then makes a further leap that maybe gamma-ray bursts arise from "Antimatter from the planetary explosion's blast wave encountering interstellar matter" (*DM*, p. 164). The mind boggles at the prospect of such an antimatter blast wave travelling outward through the Sun's planetary system. Planets, asteroids, comets and interplanetary particles would all become little gamma-ray burststars as the antimatter wave front engulfed them and mutual matter/antimatter annihilations took place at their surfaces and (in the case of the planets) within their atmospheres. If such a thing had really happened just three million years ago, it is very difficult to imagine that terrestrial life could have survived. It is far from sure that any remnant of Earth itself would have survived.

The claim that AL 26 is found in carbonaceous meteorites should also be clarified. The half-life of this isotope is only 7.17×10^5 years, so its presence in meteorites could not even date

from the time of the supposed planetary explosion. This isotope is created in meteorites by cosmic rays and is useful in determining the length of time that a meteorite “find” has been residing on Earth. Once the parcel of matter that becomes a meteorite is exposed to space, either through the breakup of its parent body or by exposure on the surface of a parent object, it is constantly bombarded by cosmic rays and it is this process that produces Al 26. After the meteorite falls to Earth, the atmosphere shields it against cosmic radiation and the production of this isotope ceases as, all the while, the Al 26 already within the meteorite decays at a rapid rate. The terrestrial age of the meteorite can then be determined by comparing the amount of Al 26 remaining. This is a useful tool provided by nature, but as it stands it has little to do with exploding planets.

The most exotic, and by far the weirdest, hypothesis concerning the cause of the explosion relies on an unconventional theory of gravity which Van Flandern adopted from G-L Le Sage who first postulated it in 1748, and N.F. De Duillier who proposed something very similar, even earlier in 1690. In this hypothesis, gravity results from a flux of invisible ultra-mundane corpuscles to which Van Flandern gives the name of C-gravitons. These particles are thought, by their few supporters, to impinge upon all objects from every direction at velocities exceeding that of light itself. In a paper given by Van Flandern in 1998, he asserted that they travel at a velocity at least twenty billion times greater than photons of light. He also thought that they could provide limitless free energy and even put them forward as a means of providing superluminal space travel. But amidst all these hopeful properties, there was a negative. All masses in the universe are inevitably absorbing energy from the influx of these particles and if the source of energy which they provide is truly limitless, what would happen to a planet if something stopped it from reaching thermodynamic equilibrium by ridding itself of the energy that it was receiving? He speculated that such might happen if an insulating layer was formed within a planet due to a change in state in that planet’s core. Unable to rid itself of this limitless influx of energy, the planet would simply blow itself to pieces (Figs. 2.7 and 2.8).

The biggest problem with this hypothesis is the very dubious state of the hypothetical C-gravitons. Nearly everyone who has



FIG. 2.7 Georges-Louis Le Sage (*Courtesy: Wikimedia*)



FIG. 2.8 Nicolas Fatio de Duillier (*Courtesy: Wikimedia*)

worked on the theory of gravity has rejected the Le Sage model as lacking in evidence. Gravity remains a mystery, but Le Sage does not appear to have provided the solution and, if this theory fails, another mechanism proposed for exploding planets fails together with it.

Captured Moons and Martian Theme-Parks

As already mentioned, Van Flandern did not believe that Mars was numbered amongst the Sun's original planetary family. Not, at least, as a true planet. It was a moon of one of the worlds that later exploded, probably Planet V which seems to have been the more earthlike of the two and which orbited close to where Mars is found today. As a consequence, Mars was not initially accompanied by its two tiny moons, Phobos and Deimos. In a rare display of harmony with the orthodoxy prevailing at the time of his writing, Van Flandern agreed that these Martian moons are captured asteroids. Indeed, he even went so far as to state that they are "certainly former asteroids" (*DM*, p. 272). This is no longer as certain as it may have appeared to be at the time he wrote those words, however. In fact, it now seems that the moons resulted from a giant impact during the youth of the Solar System, rather like a scaled down version of the impact that is widely thought to have led to the formation of our own satellite. In part, this change of opinion has come about through the difficulties encountered in getting captured asteroids into the orbits followed by Deimos and Phobos. Although there might be a certain intuitive appeal about the capture hypothesis, getting it to work in detail has proven to be far from satisfactory.

Van Flandern was very aware of the difficulties involved in the orthodox version of the capture hypothesis and it was here where he dramatically parted company with the more conventional supporters of that theory.

For one thing, because he saw asteroids as recent additions to the Sun's family, he did not accept the prevailing thesis that the capture of the moons took place long ago in the life history of the Solar System. Indeed, as Mars itself was not a free-orbiting planet until Planet V blew up, it must have been moonless for most of

its existence. All this changed about three million years ago in Van Flandern's opinion when Planet K exploded. By that time, Mars was orbiting the Sun. Many months after the explosion, the smaller pieces of planetary shrapnel reached Mars, but their velocity was too high for the small planet to trap them into orbit and most of them simply passed by. Some presumably impacted the surface but a few passed through the Martian atmosphere and, for a substantial range of altitudes, would have been slowed sufficiently by atmospheric friction to go into temporary orbits around the planet. Many of these orbits would have decayed after only a very few revolutions due to the continuing atmospheric drag. Nevertheless, the total number of these temporary moons may have been considerable and by the time the slower-moving, larger, fragments of Planet K arrived, a screen of the tiny temporary satellites surrounded the planet. The larger masses collided with these and "Among the many such collisions likely to occur, some may be suitable to leave a few of the larger masses gravitationally bound to Mars in a permanent way" (*DM*, p. 274). Continuing collision with the smaller and very temporary satellites drove these larger captured bodies into more circular and somewhat more equatorial orbits. Several small moons may have formed in this way, although Deimos and Phobos remain the only pair that managed to survive down to the present day.

Van Flandern sees the decaying orbit of Phobos as evidence for a recent capture. This moon also has remarkable grooves on its surface, which Van Flandern sees as evidence that this moon had at one time run into streams of material in Martian orbit, just as expected in his scenario. Moreover, both moons resemble C-Type asteroids; just the sort of material that he believed the exploding Planet K spread throughout the Solar System.

Probably, the biggest hurdle to accepting this account of the genesis of the Martian moons is the requirement of an exploding planet in recent Solar System history. But when we turn from the moons of Mars to some of the surface features of that planet, Van Flandern's ideas become distinctly weirder. He speculates that, prior to its explosive demise, Planet V was inhabited, not merely by animal life, but also by civilization. Upon seeing the signs of the coming catastrophe, these beings migrated to their largest moon (the future planet Mars) and survived there until the

second planetary explosion. It seems that they noticed in advance that Planet K was in trouble and had enough time to set off for the apparent safety of Earth before it blew itself to pieces. Van Flandern suggests, albeit only as a hypothesis, that these “intelligent inhabitants of the dying planet might have intervened directly in the evolution of species on Earth, so as to produce an intelligent species here” (*DM*, p. 341). In that way, the strange coincidence between Planet K’s explosion and the appearance of early hominids on Earth ceases to be a coincidence at all. Alternatively, he suggests that the extra cosmic radiation from the blast of Planet K may have sped up terrestrial evolution or, maybe, killed off some natural enemy of the primates, thereby allowing this species to multiply and diversify.

Now, if a civilization had once been present on Mars, we might expect that remnant signs of this might still be observable. In the opinion of some radical thinkers, this is exactly what has been found. These are the famous—or infamous depending upon your point of view—pyramids and face. The face in particular has drawn a great deal of wild speculation, although most of this was based upon early and relatively low-resolution images. Later images show the superficially artifactual appearance of this formation to dissolve into random markings. In *Dark Matter*, Van Flandern takes a skeptical view of the subject, in the true sense of the word “skeptical”. By that, I mean that he leaves open for further investigation both the possibility that these features found on the surface of Mars are artifacts of a vanished civilization and the possibility that they are simply natural formations which superficially resemble something artificial. He apparently leaned toward the second more conservative opinion stating that “Most probably [they are] natural rock formations which by chance had taken on forms of interest to humans, the way a cloud in the sky might occasionally do if one is looking for shapes (*DM*, p. 346).”

It is indeed interesting to note just how often faces and human forms in general appear in natural formations. In the present writer’s home state of New South Wales, there is a hill overlooking the tiny village of Wingen in the Hunter River Valley that bears a striking resemblance to the profile of a woman. The Wingen Maid is even named on maps of the area, yet nobody

has suggested that it is artificial. Moving to a more unearthly example, can you detect the “smiley face from outer space” in the image of Stephan’s Quintet (Fig. 2.7)? Van Flandern’s statement in *Dark Matter* is surely correct. And yet, he has over time become associated with the more extreme opinion that these formations really are the work of an ancient civilization. In later articles and public lectures he even suggested that the face might have originally been constructed as a sort of theme park or museum. In Australia, we have structures like the Big Banana, Big Marino and so forth which seem to resemble the sort of thing about which he was thinking. Did Mars perhaps have a Big Face? (Fig. 2.9).

One wonders if Van Flandern really, in his heart of hearts, believed any of this or whether he was simply stirring the pot to get people to think outside the box of conventional scientific method. He apparently believed in the possibility that this could be correct, but that is not the same thing as believing in the actuality. What his real thoughts were can only be surmised.



FIG. 2.9 Stephan’s Quintet, complete with “smiley face” (Courtesy: NASA)

Project 2.1: The Faces in Outer Space

Simply as a matter of curiosity, examine some of the images of the surfaces of Mars, Pluto, Mercury and so forth taken from flyby or orbiting spacecraft and see how many faces and other formations can be found that might be cited as artifacts by someone committed to finding evidence of intelligent extraterrestrial life. I am not suggesting that any of these formations really *are* artifacts, but it is interesting to find just how often artificial patterns can be read into perfectly natural formations. Try it and see for yourself.

Be that as it may, it is difficult to believe that any hypothetical “Planet V-ians” could have survived all of this turmoil. Granted that Planet V must have been a smaller planet than Planet K and so is unlikely to have gone off with the force of a classical nova explosion, it still seems incredible that an intelligent race could have simply hopped over to one of the planet’s moons and then used this as their successful Noah’s Ark while the parent planet blew up all around them. Although we don’t know what triggered the explosion, it must have been violent and, if it also marked the birth of S-Type asteroids in the manner that Van Flandern speculates, an awful lot of planetary debris must have whizzed past the moon Mars, with a great deal not going passed at all but actually impacting the surface. As we earlier saw, Van Flandern gives several possible mechanisms by which a planet might explode, some of which would have resulted in a rather nasty blast of radiation. None of these looks very convincing, as we argued, but if the planet actually exploded and was not simply struck by a huge meteorite (which must have been rare in those days, unless an even earlier planet exploded within the inner Solar System) one might conclude that some violent process producing a good deal of radiation was probably involved. Given that Planet V was, according to this scenario, apparently inhabited by creatures with sufficient intelligence to build spaceships capable of transporting them to one of its moons but not necessarily intelligent enough to avoid building atomic weaponry, one might even dare to suggest that they blew the planet up themselves. Van Flandern does not consider this possibility however, and there are some clear objections to it. His hypothesis

of exploding planets is clearly based upon the occurrence of natural processes. Moreover, if the inhabitants of Planet V destroyed their own world, it is probable that they would not have known of the catastrophe in advance and would not have had time to prepare for, and execute, their escape, though one might argue that they already had a colony established on Mars and that it was the inhabitants of this that survived. In any case, the survival of life on the moon of an exploding planet remains a very dubious scenario.

Nevertheless, a worse situation must eventually have followed with Planet K going up in an even bigger blast. Apparently Mars, long since a planet in its own right by that time, was deemed too close for comfort, but I strongly doubt that Earth would have been in a much safer position, as mentioned earlier. Maybe *bacillus infernus*, living deep down within the planet's crust, might have survived, but I doubt if anything else would have, be that native or alien life.

Alien Intervention in Terrestrial Biology?

Going back a little way to the earlier remark regarding the possible effect on terrestrial life of these hypothesized planetary explosions, we recall that Van Flandern suggested the possibility of a very direct influence via the manipulation of terrestrial life by intelligent beings from Planet V (via Mars) who fled to Earth when they saw Planet K giving signs of its impending blast. Overlooking the difficulties raised by exploding planets in general and their devastating effect upon life on other planets within their home systems in particular, we might wonder whether this recurring theme of alien intervention rests on anything that might be construed as firm evidence. Alien intervention does not depend upon the hypothesis of an exploding planet. It does not even depend upon Mars or one of the other Solar System worlds having been inhabited by intelligent space-faring beings at some time in the past. If we are going to speculate, let's be really daring and suggest that somewhere in the Galaxy a race long ago achieved interstellar travel and visited Earth three, four, or more millions of years ago. At least, let us suggest this if only for the sake of speculation. Is there anything that might allow this suggestion to be taken seriously?

Several decades ago, the name Erich von Daniken made headlines around the globe following the publication of his best-selling

book *Chariots of the Gods?* and its sequels. Very briefly, what this author suggested was that ancient beliefs and legends of gods and heroic beings might actually have been based on half forgotten accounts, handed down from one generation to the next, of actual contacts between human beings and visitors from another planet. The “gods”, in short, might have been alien astronauts!

This book created quite a stir, to put it mildly. Although *Chariots* was presented as a possible explanation for stories of gods and so forth (as was implied by the question mark at the end of its title), many folk simply accepted it without question as fact. Book sellers at the time remarked that many customers were purchasing the more expensive hard cover editions rather than the cheaper paperback and interpreted this as indicating the value that they were placing on the work. It was something to be kept and given a place of prominence amongst their collection of books, not a quick-read paperback that might then be discarded or donated to the local charity book stall.

In the subsequent books, von Daniken assumed a more dogmatic and extreme position and his ideas came under increasing examination by skeptics. His claim that ancient artifacts were probably the work of extraterrestrials was criticized by many anthropologists who argued that far simpler explanations, involving only humans and their hard work and capacity for innovation, were quite adequate to account for the statues, temples and rock artwork of ancient times. Some of von Daniken’s supposed evidence was exposed as downright fraudulent. For example, a ground marking shown in a photograph in one of his books which he claimed to be the remains of a prehistoric airport was found to be a tiny feature hardly large enough to fit a model aircraft. It looked superficially convincing, as long as there was nothing to demonstrate its scale. Add a human being, towering over the marking, and its true dimensions became all too apparent. Allegations of even more extreme misrepresentations have been made. For example, one critic claimed that the discovery of certain alleged ancient works of cave art apparently revealing incontrovertible evidence of alien visitation and shown to von Daniken by a native of the region in which they were found, apparently had no existence outside the author’s mind. The person who allegedly revealed this ancient treasure to von Daniken was later questioned about the

subject, and informed his interviewers that they had the story back the front. He had not told von Daniken about anything. It was von Daniken who had informed *him* about the ancient art.

Thanks to this increased skepticism about that author's claims, von Daniken's "Chariots" have by now largely ridden off into the sunset taking their extraterrestrial "gods" with them.

Von Daniken is mentioned only twice by Van Flandern in *Dark Matter*, but it is clear that the latter took his views seriously in the sense that he considered them to be worthy of proper scientific investigation. He even went so far as to state that he believed the hypothesis of contact between humans and extraterrestrial visitors was superior, in explaining the similarities found in ancient artifacts and stories, to the competing orthodox theses. He argued that the ancient astronaut hypothesis was more obedient to the scientific principle of Occam's Razor in so far as it involved fewer assumed hypotheses than the more widely accepted opinions. In view of the criticism of von Daniken however, that position is difficult to justify. Even if we are very charitable toward von Daniken and excuse his falsification of some of the presented evidence as due to his unbridled enthusiasm in getting his point across, it remains true that no artifact put forward as being possibly alien was clearly and demonstrably outside of the manufacturing capability of the humans alive at the time it was constructed. We must rid ourselves of the idea that people of our own time and culture are unique in their abilities to invent clever ways of doing things. A quick glance at the Roman aqueducts, the early Buddhist temples and mediaeval cathedrals is enough to ensure us that there were great buildings before what we like to call the modern age. And if we admit these as human works, then why not extend the same courtesy to, for example, the ancient Egyptians and their sphinxes and pyramids?

The latter, although often featuring in lists of wonders that some people believe required superhuman intervention, can be clearly seen as human works if we trace their evolutionary development from simpler forms of tombs. Egyptologists found that these earlier types of tombs were rectangular structures with flat, slab-like roofs and outward sloping sides. Such a structure is known as a mastaba, literally meaning "house for eternity". The next phase was effectively placing one of these structures, or

something closely approximating it, on top of another and thereby growing a step pyramid. These were the earliest forms of Egyptian . pyramids, prior to the final phase which we might call the filling in of the steps to give the smooth and regular . pyramids which became so symbolic of that country. While Egyptologists might be gnashing their teeth at such a brief account of. pyramid evolution, the general picture is sufficient for our present purpose. What it shows is that there is no need to introduce extraterrestrials at any point in the process (Fig. 2.10a and b).

What really would turn the tables in favor of the hypothesis of alien intervention would be something like the discovery of an ancient . pyramid of pure titanium, a transistor radio in a 2000-year-old undisturbed tomb or a silicon chip in ancient geological strata. Thus far, no such artifact has turned up.

Maybe von Daniken was too controversial even for Van Flandern, as his mention of this author is brief, as already noted. More space, albeit mostly in an extensive footnote, is afforded in his book to Zecharia Sitchin. Unlike von Daniken, Sitchin did not amass examples of ancient artifacts which he claimed could not have been constructed without alien help. Rather, he relied on ancient writings, claiming that stories of encounters between humans and gods or other supernatural beings had their origin in real encounters with extraterrestrial visitors.

Briefly summarized, Sitchin's hypothesis states that at the beginning of human existence, extraterrestrials landed on Earth and genetically engineered a species of hominid (humans) to serve their labor requirements. These genetically engineered hominids were made in the likeness of the extraterrestrials themselves and commanded to serve their masters. They were also kept in ignorance of certain subjects, knowledge of which their extraterrestrial masters considered to "dangerous" for them to acquire. None the less, the inquisitive humans managed to acquire this knowledge anyway, and were cast out of the presence of their alien masters and driven away from their protection. However, the humans continued to multiply and even cross-bred with the aliens themselves. The situation became so bad that the aliens decided to wipe them from the face of the planet, although not before they selected a very small number of superior humans whom they protected from the cleansing catastrophe. Nevertheless, subsequent

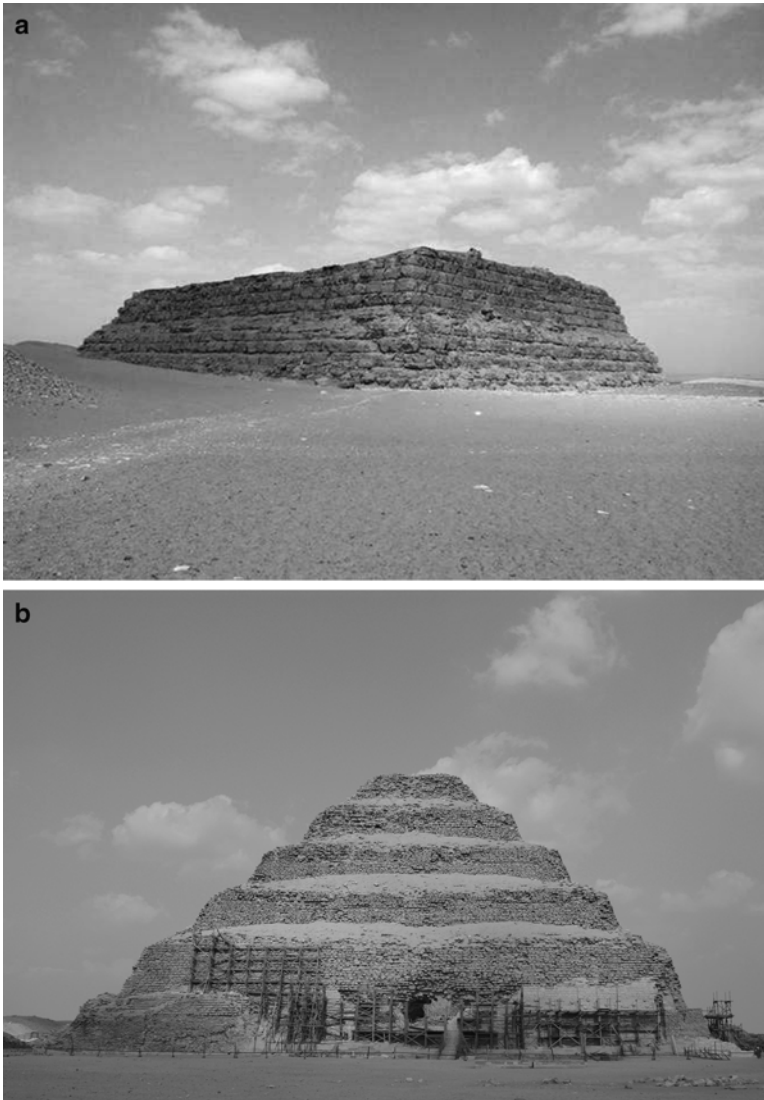


FIG. 2.10 (a, b) The evolution of Egyptian tombs from mastaba to stepped pyramid (*Courtesy: Egypt archives*)

descendents of these chosen humans sought to imitate the aliens by constructing a spaceship capable of carrying them to the dwelling place of the alien masters themselves. This attempt was especially worrying to the aliens and they became deeply concerned that humans might go on to develop even more advanced technology; with possible dire consequences. In order to put a stop to

this human arrogance, the aliens caused a scattering of the human race through the confusion of their languages. Apparently, even this did not work and the aliens eventually gave up on the human race and went back to their home planet.

If this sounds vaguely familiar, that is no surprise. It is essentially a re-writing of the Book of Genesis with the assumption that God referred to the alien master race. Further speculation by Sitchin has Sodom and Gomorrah being destroyed by nuclear weapons and the Pyramids of Egypt constructed as nuclear bomb shelters.

Van Flandern laments that most of his colleagues irrationally react negatively to such considerations as these. As an example of what a more rational reaction might be, he suggests that "sediment samples from the bottom of the Dead Sea should be quite definitive in determining whether or not nuclear weapons were used on Earth long ago" (*DM*, p. 340 f). The reader might like to construct a mental fantasy about a researcher approaching his or her department for funding to conduct a sampling of the Dead Sea floor to determine if nuclear weapons destroyed the cities of Sodom and Gomorrah back in the days of Abraham! Somehow, I think that funds would be directed elsewhere, but not because of closed-mindedness amongst scientists, as Van Flandern believes. It is simply that for a suggestion to be transformed into a true hypothesis, hard evidence must be forthcoming. Yet, the evidence for Sitchin's scenario is weak to say the least. For one thing, if a highly technological alien race had lived on Earth for thousands of years, one might expect some remnants of their technology to have survived, at least in ruined form. This point was made earlier in the context of supposed ancient alien artifacts, but it is relevant here as well. It is one thing to say that the pyramids were nuclear bomb shelters and that "this makes ever so much more intuitive sense than the concept of a tomb for a pharaoh" (*DM*, p. 340f), but when no evidence of nuclear blasts in the Egyptian desert (forget the Dead Sea for the present) has been found, when mummies of pharaohs turn up in pyramids, when the evolution of pyramids from earlier tombs is quite obvious and when the entire tomb building enterprise so clearly blends with the ancient Egyptian view of death and the afterlife, the bomb-shelter idea not only ceases to make more intuitive sense, it begins to verge on the

absurd. It might, in our own culture, appear more fruitful to spend the immense investment of money, time and labor on nuclear bomb shelters than on tombs, but that does not fit with the thinking of an ancient Egyptian. Even if nuclear weapons had existed in those distant times, there is no certainty that shelters would have won the day over tombs. After all, what would have seemed more important to an ancient Egyptian; preservation of life in this world for a few more years or keeping it for eternity?

What is arguably the biggest problem encountered by all of these hypotheses of ancient astronauts or whatever we might call them is that nothing has turned up in archaeological digs that is radically inconsistent with the technological achievements of human culture as it existed at the estimated age of the material found within these ancient sites. This alone suggests, as already stated, that in the absence of very strong evidence to the contrary, humanity was responsible for whatever artifacts are found. At the risk of laboring the point, we repeat that if a laser is ever dug up in a Stone Age tomb or a fossilized computer chip found in million year old sediment, then the prospect of ancient alien intervention will at least have some empirical evidence that is convincingly solid enough for serious consideration. But drawings on cave walls which might represent spaceships if seen with the eyes of faith but might just as easily be diving birds with their wings folded are simply not enough to support such farfetched speculations.

Nevertheless, whilst we make no apologies for being critical of Van Flandern's hypotheses, we welcome any ideas that make us think again about the hypotheses that tend to get taken for granted and treated almost as absolute truth. We remember that in the late nineteenth century, one of the eminent scientists of the day wrote that the most firmly established scientific fact of all was the existence of the ether, the supposed all-pervading substance believed necessary for the transmission of electromagnetic waves. Not long after these words were spoken, Michelson and Morley, in attempting to measure the ether drag as Earth passed through this substance, actually succeeded in demonstrating its non-existence. Then, closer to our own time, the British Astronomer Royal made his (in)famous statement to the effect that space travel "is all bilge" just a few years prior to the launch of the first artificial Earth satellite and just over a decade before astronauts landed on

the Moon. Scientific theories and opinions can become dogma if not challenged. We need our Van Flanderns with their unconventional and downright weird theories. Whether we agree with them or not, they provide the challenges that open our minds to other possibilities. May they keep coming!

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