

IRG23: The Ultimate Rocket, the Ultimate Energy Source, and their Use in the Ultimate Future

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Reviewed by Atholl Hay

Atholl Hay is a software engineer and physicist. Here he reviews a paper that Professor Frank J Tipler presented at IRG23 which has long term implications for rocketry, our species and the entire universe.

Notes in this article are endnotes rather than footnotes.

Prof Tipler's talk is at www.youtube.com/watch?v=drXvzuTmhFQ.

In this paper Professor Tipler seeks to establish the theoretical limits to interstellar travel that may be deduced from our current knowledge of modern Cosmology and Particle Physics. In some cases (rocket propulsion), there is a degree of plausibility; in others (the future of the universe) there is a degree of controversy; but in the case of the "ultimate future" we enter Prof Tipler's personal Wonderland. In the following short paragraphs I shall attempt to summarise the content of the four main sections of the paper and then finish with some brief concluding remarks.

1. The Ultimate Rocket and Ultimate Power Source

The accepted metric by which the performance of a rocket propulsion system is measured is the "specific impulse" (in seconds) which is defined by the relation

$$\frac{\text{impulse}}{\text{weight}} = \frac{F\Delta t}{mg} = \frac{m\Delta v}{mg} = \frac{\Delta v}{g} \text{ s}$$

- with force F , time increment Δt , fuel mass m , gravitational acceleration g and velocity increment Δv .

The theoretical maximum specific impulse is the quantity $I_{sp} = c/g$ (where c is the speed of light) which equates to 30,570,300 seconds which is around 353 days or just short of a year. Prof Tipler gives the specific impulse for several previous or current chemical rockets, the best of which are the SpaceX Raptor at 375 seconds and the Ariane third stage at 446 seconds. Given that the specific impulse for the German V-2 rocket was 239 seconds Prof Tipler concludes that we have not come far and we have a long, long way to go. The reason for this minimal progress he argues is the continued reliance on chemical reactions in propulsion systems.

A commonly advanced alternative propulsion system and one made possible by the commonly quoted "laws of physics", is one that uses matter/anti-matter annihilation to produce a photon exhaust travelling at the maximum velocity.

◀ Prof Tipler argues against this however on the practical grounds that the production of anti-matter entails the production of an equal amount of matter that is then discarded. His proposed alternative is a process:



in which a proton and an electron combine to form two photons forming what he refers to as the “ultimate energy source”.

However for rocket propulsion he prefers, on environmental grounds, the process



in which a proton and electron combine to form a neutrino and an anti-neutrino which travel at close to the speed of light and with minimal tendency to interact with surrounding matter.

Both these processes are advanced by a lengthy argument which runs roughly as follows.

(1) The early universe created matter by means of a process known to particle physicists and cosmologists as “baryogenesis”. The absence of anti-matter in this process is believed to be related to a very slight initial imbalance in quarks and anti-quarks for which there is no current explanation.

(2) Baryogenesis can be understood in terms of the Standard Model of Particle Physics provided certain conservation laws are suspended by so-called “Sakharov conditions”. In particular, the laws that conserve baryon and lepton number must be rescinded to prevent the creation of an equal number of anti-matter particles.

(3) The early universe contained a pure radiation field which satisfied the Sakharov conditions and permitted the creation of matter by means of the process



where two photons combine to produce a proton and electron pair.

(4) Any process described by the Standard Model that goes one way can, “in appropriate circumstances” (to use Prof Tipler’s words), be made to go the other way, which results in the ultimate energy source described in equation (1) above.

Since Prof Tipler is concerned only with theoretical prediction rather than engineering reality, he is able to confess he has “no idea” how to reverse the matter creation process (3) to achieve the energy source (1). However he does not address the difficulty of the Sakharov conditions which if applied to enable matter production in (3), must surely also be applied in the reverse process of energy production (1). For as any text-book in Particle Physics will point out, process (1) violates the law of conservation of electron number L_e which is 1 on the left-hand side of (1) and (2), and 0 on the right. Surely then, some modification or dark recess of the Standard Model unknown to this author is being applied here.

Towards the end of this section we enter briefly Prof Tipler’s Wonderland for he states that the ultimate energy source will, by reducing the matter content of the universe, decrease the cosmological constant (which he equates to Dark Energy), and turn off the current acceleration of the expanding universe. He does not estimate the scale of interstellar travel powered by the ultimate energy source that would be required for this to happen.



◀ 2. Experimental Evidence for the Standard Model Baryogenesis Mechanism

According to Prof Tipler the matter creating process described in terms of the Standard Model by process (3) was facilitated by a radiation field which was present in the early universe, and if this field survived to the present day, then it constitutes the Cosmic Background Radiation (CBR). However the Sakharov conditions require this field to have interacted with the Higgs field in the early universe making it “almost photonic” so that the CBR is comprised of particles that Prof Tipler refers to as “pseudo-photons” as opposed to the “pure photons” that are normally associated with electromagnetic radiation.

In support of this claim, Prof Tipler has conducted experiments to investigate the nature of the CBR which involve measuring the spectrum of the radiation passed through a Fabry-Perot interferometer which contains a variable number of highly reflecting silicon disks. According to Prof Tipler’s calculations, pseudo-photons should be scattered less than pure photons by the electrons in the silicon resulting in changes to the spectrum of intensities of the emergent beam. The apparatus also contains a screen by which ground-reflected CBR may be admitted or prevented from entering the interferometer with the aim of showing that when pseudo-photons are reflected they are in fact converted to pure photons. This, Prof Tipler maintains, is why “pseudo-photons” have not been detected hitherto.

The spectrum predicted for pure photons in the frequency range 7 to 14 GHz is reproduced in the paper and consists of a U-shaped curve with a single flat-bottomed trough flanked by two sharp peaks of equal height. By contrast, the spectrum predicted for a CBR comprising $5/8$ pure photons and $3/8$ pseudo-photons transforms the curve into a W-shape with a smaller central peak lying between the other two. The results recorded by a custom-built spectrum analyser attached to the interferometer show an approximate correspondence between theory and observation. However several factors, including the screening off of reflected radiation and the small number of observations (three evenings over a period of “several years”), suggest that it is premature to announce the discovery of the pseudo-photon. Nevertheless Prof Tipler seems convinced that his theory of baryogenesis involving a radiation field containing pseudo-photons is correct and that a reversal of the process will eventually be used to power the ultimate rocket.

3. The Ultimate Future

In Prof Tipler’s view the “laws of physics” mandate an ultimate future in which the universe expands to a maximum finite size and then contracts to a final singularity. This is in contrast to the current view that the more likely future is one in which the universe expands continuously over a very long period of time into a low-temperature equilibrium state sometimes referred to as “heat death”. Since this would require the complete evaporation of black holes by the emission of Hawking Radiation, Prof Tipler argues against this on the grounds that it violates the quantum mechanical principle of “unitarity”. Essentially, this states that the evolution of a wave-function is symmetrical in time and this implies both the conservation of its information content and the conservation of energy. As mentioned above, Prof Tipler believes the reversal of expansion will be accomplished by the extent to which our distant descendants can exploit the ultimate energy process described by equation (1). Prof Tipler also argues that Roger Penrose has pointed out that violating unitarity in Black Hole evaporation leads in turn to a violation of the Second Law of Thermodynamics, but Prof Penrose in turn maintains [1] that due to time-related subtleties in the general relativistic description of black-hole evaporation, one cannot say definitively when the entropy disappears and that entropy in any system outside the black hole continues to evolve according to the Second Law.

4. Constructing a Universal Computer

In the final section of Prof Tipler's paper we finally enter his Wonderland in which "we" (the human race) "are the only intelligent species in the universe", and that moreover "we" are unique because if other intelligent life forms existed, they would have already used up the matter in the universe. For reasons that are not stated clearly this compels our descendants to construct a "universal computer" which is in effect a Universal Turing Machine in which the infinite tape is replaced by an infinite memory. Based on a quantum mechanical relation called the Bekenstein Bound which establishes the limit to the thermodynamic entropy contained within a finite volume of space, Prof Tipler estimates the possible memory capacity of the ultimate computer to be of the order of 10^{30} terabytes. This is well beyond the capacities of the current generation of supercomputers which have memories of the order of 10^4 to 10^5 terabytes.

In Prof Tipler's view, computers of this magnitude will in the far future "be able to resurrect us all in virtual reality" thus conferring the status of immortality upon our lucky descendants. He regrets that others such as Profs Penrose and Hawking should feel obliged to renounce the principle of unitarity and the Second Law of Thermodynamics and therefore be reconciled to the certainty of death. Fortunately, he concludes, "the laws of physics" are against them.

5. Concluding Remarks

My summary above omits considerable technical detail in Prof Tipler's paper which will be understood only by those with graduate knowledge of particle physics, modern cosmology and general relativity. On the other hand, those so equipped may find much to disagree with particularly in relation to the future of the universe and Prof Tipler's particular views on the nature and origin of quantum mechanics. Perhaps the most useful information to be gleaned by non-specialists is that contained in the first section on the limits to rocket propulsion.

Finally, a note of caution to those attracted by the phrase "according to the laws of physics". Starting from precisely the same set of laws Profs Tipler and Penrose apply their preferred set of caveats to reach precisely opposing conclusions regarding black-hole evaporation. Prof Tipler believes that complete evaporation violates the principle of unitarity and the second law of thermodynamics and this leads him to conclude that the universe must ultimately collapse to a final singularity. Prof Penrose on the other hand argues [2] that the violation of unitarity is "a necessary reality" but is nevertheless able to rescue the second law and to propose a cyclic cosmological model called Conformal Cyclic Cosmology in which the universe iterates through infinite cycles of time called aeons. In the continuing absence of experimental evidence for either scenario, perhaps our distant descendants resurrected in Prof Tipler's ultimate future will be the only ones around to discover who is correct.

6. References

- [1] Roger Penrose, Cycles of Time: An Extraordinary New View of the Universe, Vintage, pp 188-189.
- [2] Ibid, p 186.