Stutterwarp Misconceptions

From Lucien S. Maréchal, *History of the Jerome Drive*, Madsen Publishing, Paris 2306

Exactly what did he say?

It is a widespread misconception (especially in the anglosphere) that upon seeing his effect Dr Jerome said: "One small step for an electron; one giant leap for Mankind."

First, the famous 2086 experiment involved a hydrogen molecule, and second, the real source was Dr Jerome's colleauge Dr Frédéric Cazals. Dr Cazals, an awowed anglophile and space enthusiast, said the above when he and Dr Jerome first demonstrated that the direction and distance of the tunneling could be controlled in 2087 using an electron beam.

In the case of the far more important directed tunnelling of a hydrogen atom August 18th 2086 Dr Jerome said, after having been shown the now famous graph, "C'est quelque chose d'intéressant à méditer." "That's something interesting to think about."

When did the first jump occur?

There is some confusion here as people mix up Dr Jerome's important experiment in 2080, which established quantum teleportation of a hydrogen atom, and the 2086 demonstration of quantum tunneling of a hydrogen molecule. Quantum teleportation is fundamentally different from directed tunneling. The 2080 experiment, published as

> Joachim Reichel, Sébastien Loriot, Mario Botsch, Pierre Alliez, Emile J. Jerome, Deterministic quantum teleportation with atoms, *Nature* 657, 734-737 (17 June 2080)

demonstrated that the quantum state of an atom could be transmitted using a carrier particle to induce an identical state in another atom. This represented the then pinnacle of Dr Jerome's work in quantum teleportation, a field he more or less single-handedly created in the 2070's. While of profound theoretical interest it has so far not led to any real applications, and the discovery of the induced tunneling effect made Dr Jerome turn his genius elsewhere. However, many of the methods and formalism for multiatom entangelement that were developed by his team in Grenoble were cruicial for the next step.

The 2086 experiment led to the paper

> Frédéric Cazals, Sébastien Loriot, Henri Rivière, Emile J. Jerome, Induced Macroscopic Quantum Tunneling, *Le Journal de Physique* 65:3, 1-12 (12 October 2086)

which is "the" paper on true induced tunneling. It did not use any carrier particles and actually transmited information faster than light. It still did not control where the atoms ended up, just that they tunneled. Finally, in 2087 the paper

> Frédéric Cazals, Sébastien Loriot, Emile J. Jerome, Induced Macroscopic Quantum Tunneling with Deterministic Direction, *Le Journal de Physique* 67:5, 43-55 (5 December 2087)

demonstrated that the tunneling could be directed in a reliable manner, inspiring the scientific community to begin researching a stardrive.

The Jerome effect

The technical term is "Induced Macroscopic Directed Quantum Tunneling", but since 2090 the Jerome effect has been the standard term. Like any scientific breakthrough it is problematic assigning a single discoverer to it. While Dr Jerome was cruicial, it could just as well have become known as the Jerome-Cazals effect or the Jerome-Cazals-Loriot effect.

Unfortunately Dr Cazals died in 2099, the year before Dr Jerome received the Nobel Prize for his work on quantum teleportation and tunneling. Otherwise he would likely have shared the prize with Dr Jerome. Sébastien Loriot was a Ph.D. student of Dr Cazals and did much of the technical work with him; that the prize committee did not acknowledge him plagued him for much of his life, until in 2142 he received his own Nobel Prize for drive stabilization theory.

Background theories

Americans often mention trans-modular phase series and the work of April Choi as the source of the 2086 experiment. This conveniently ignores that while the 2086 experiment was an attempt to disconfirm the Choi Inconsistency Conjecture it would eventually make the whole theory obsolete.

Dr. Emile Francoise Jerome was first and foremost a keen experimentalist, not particularly fond of overly theoretical work. One reason he set out to test the Inconsistency Conjecture was his stated belief in a consistent, objective (at least in a quantum mechanical sense) universe. He clearly stated in the 2086 paper that while the experiment fitted with the conjecture it did not confirm it, and he privately confided in several associates that he thought the Conjecture was false. He was proven right posthumously.

Another reason he performed the experiment was that he was the only one who could: his expertise in quantum teleportation and managing neutral entangled particles was preeminent at the time. When interest in the physics community for this form of entangled states arose, Dr Jerome was the natural experimenter.

The Grenoble and CERN results led to a great interest in trans-modular phase series and fine-grained inconsistency theories in the 2090's and 2100's. Unfortunately the field did not pan out: when further inconsistency cases were tested they were found to be consistent, and the uncomputability of phase series made them useless even for theoretical predictions. Meanwhile Jerome's experimentalist approach flourished, demonstrating the rich phenomenology of directed tunneling and discouraging too fanciful theorizing.

The eventual demonstration that the Choi Inconsistency Conjecture was wrong occurred in 2148, when Abdelkrim Mebarki finally proved the Mebarki Consistency Theorem. As he is reputed to have said, "The universe is finally complete." (others claim he said "The universe is trival, so it has to be complete.") However, the interest in Gödelian physics stimulated major mathematical advances in the 22nd century, in particular the theory of alpha-consistent domains and Choi assemblages. This has in turn stimulated the large field of trans-Gödelian Kripke semantics in mathematical philosophy.

As for the theory of the Jerome Effect, the experimental data was finally unified 2106 into the Raab-Delage-Reböfat (RDR) model of supermanifold vaccum geometry resonance, the foundation for all modern stardrives. This was in turn put on a firm theoretical foundation by the quantum information geometry of Eugene Woodworth in 2165.

[Choi and her theory due to Levy Ben, http://www.geocities.com/levybenathome/NYC2300]

Are all stutterwarps in starships?

"Lab drives" are employed in various areas of research; mainly drive development, materials science and theoretical physics. They are external drives moving matter from their interior to a nearby location, rather than the internal drives on spaceships that move themselves too. Unless used on individual atoms like Jerome's original setup in Grenoble, lab drives are nearly always located in space stations well away from heavy bodies and major spacelanes. They also commonly employ other isotopes than tantalum, for cost purposes.

One of their many uses is to cause the local tunneling of one material into another. This provides a way of imposing very high densities or exotic crystal states on samples. It is rarely used for manufacturing except for high-energy quantum 3D doping, an expensive process where individual atoms are tunneled into a workpiece in a particular pattern.

Do all drives use tantalum?

While the stutterwarp drive is usually identified with "tantalum coils" not all Jerome effect drives use tantalum.

Tantalum 180m is needed because it is a nuclear isomer of Tantalum 180: the conformation of the atomic nucleus is in a (75 keV) higher energy state than in the other isotope, yet stable over 10^{15} years. This is enough to provide the necessary quantum mechanical leverage for the Jerome effect through a process known as J-mixing, where the population inversion of nuclei can interact with vacuum spin.

As the drive accumulates gravistatic charge the probability of decay into the ground state increases exponentially. Since the probability is normally exceedinly low this is not a problem. But once the charge reaches a critical level the decays increase very quickly, and at 7.7 lightyears the emissions of gamma rays induce neighbouring tantalum isomers to decay in a cascade. Since ground state tantalum 180 is also unstable and rapidly decays, the result is a combined gamma ray detonation followed by a "small" nuclear detonation.

However, the isomer Hafnium 178m2 has an even higher energy (2.4 MeV). It is not as stable as tantalum 180m, having a half-life of 31 years, but could in principle be used in a stutterwarp. This was indeed used in some early drive prototypes. The use of hafnium proved troublesome since the isomer had to be produced in nuclear reactors and the shorter half-life made it significantly radioactive. While the ground state isotope is stable and would not produce any nuclear detonation during a breakdown the harder gamma rays from a breakdown cascade are far more serious than the tantalum case. Worse, as charge accumulates the drive becomes radioactive earlier than a tantalum drive. Shielding the drive coil superconductor from irreversible gamma-ray damage has been attempted again and again, but so far with no success. Since a hafnium drive would make many nations lacking tantalum access able to reach the stars this failure is definitely not for lack of trying – hafnium drives have been studied intensely for almost two centuries.

The Ebers are believed to have used a hafnium drive, and theoretically it could have had a longer range than a tantalum drive (due to the higher isomer energy, which gives it a greater capacity for gravistatic charge). Unfortunately it is not known how they handled the gamma ray issue.

A few other nuclear isomers have been used in laboratory drives and experiments, including Technetium 95m, Americium 242m and Uranium 235m. However, the extreme stability of tantalum 180m makes it uniquely useful for drive manufacture.

Do you have to discharge into a gravity well?

The gravistatic charge is due to J-mixing of nuclear isomer angular momenta with vaccuum spin: it is not unlike charging a capacitor. When placed into a region of spacetime curvature a drive in discharge mode will couple with the local vacuum, transferring spin to the local gravitational fields (technically, graviton-nuclei interactions decohere the J-mixing).

This discharge occurs anywhere there is spacetime curvature, i.e. anywhere in the universe. The process is however so slow outside fields of 0.1 G curvature that it is practically impossible. As an experiment researchers at the Grenoble Institute of Technology put a charged drive on Ceres, measuring its discharge in the local 0.028 G gravity. They found that it took more than 27 times longer than in a 0.1 field. The time needed seems to scale with the inverse cube of the gravity: discharging in free space, even inside a solar system, would take millions of years.

Drives could discharge much faster in strong gravitational fields, for example by bringing them down on planetary surfaces. This is rarely practical, and starship security regulations use 24 hours as a reliable standard: at that point the drive will be fully discharged in a 0.1 G field. Attempting to take shortcuts are likely to lead to disaster since the charge is not easily observable when the drive is not close to saturation. The phenomenon of mixing domains, where small patches of the coil retain significant charge, also seems to occur more readily in strong fields.

It should be noted that a drive would in theory be able to discharge into a strong beam of gravity waves. Unfortunately we lack any ready source of gravity waves of the necessary intensity. Experiments at Augereau Station with the Bohl black hole have confirmed the theory, at least.

The first drive breakdown was an accident

Professor Marie Cordiez showed theoretically in 2117 that a stutterwarp drive would accumulate gravistatic charge and would in the end break down. This follows fairly elementary from the RDR model, so the issue was by no means unknown. In fact, it was subject to much debate among the critics of the drive projects and their supporters.

The first in-system experimental drives were also carefully monitored for breakdown, confirming the Cordiez prediction. In 2130 the ESA *Menoetius* probe was launched to explicitely check the limit, and it detonated as predicted in the outer solar system after having circumnavigated it several times. The 2136 flight of the *Prometheus* probe was cautiously set up so there was no risk of getting close to the limits.

The first drive breakdown on a manned ship, the *Thibault Malandain* in 2165, was definitely an accident. The disaster directly led to the formulation of the 24 hour requirements of dischage and tighter control over route planning and drive maintenance.

Is the breakdown completely useless?

Throughout the 22nd century several military powers were engaged in top-secret and extremely expensive research on the possibility of turning the drive breakdown into a weapon. In the end it was concluded that it made a way to generate a big,very expensive gamma ray blast but little else. The idea of “gravistatic bombs” fell to the wayside.

There was also interest in whether external influences could overload or disrupt the drives of enemy ships. This approach also did not pan out; it was far simpler to disable the ships with conventional weapons. Some of the results of this area might however be used to build sabotage devices that impair drives when placed onboard ships. No nation has ever admitted to building such a device.

Another, slightly more fruitful, side effect of the studies of drive breakdown was nuclear isomer gamma ray lasers. A few were tested; however, given the importance of tantalum for drives only hafnium would be viable. Rather than use these overly expensive (if powerful) weapons much of the insights instead helped make the current nuclear-powered x-ray lasers possible.

Stutterwarp jumps do not act as time travel

Special relativity shows that since there is no true ‘simultaneous’ defined for all observers any form of faster than light travel can be turned into time travel. This is not normally observed due to two reasons.

The first reason is macroscopic: for all practical purposes starships and solar systems are almost at rest relative to each other; the time travel effects show up most clearly if speeds involved are close to lightspeed.

The second reason is microscopic: the Novikov self-consistency principle states that if an event exists and that would give rise to a paradox, or to any "change" to the past whatsoever, then the probability of that event is zero. This is due to quantum mechanical interference, where the wave function of the event from the future neatly cancels the wave function from the past. The effect is that any attempt to communicate or change the past will either fail or “already be there”.

The first clear demonstration of time travel was done already in 2094 at CERN, where Carlini and his team used an early drive setup to send relativistic electrons into their own past or future. His experiment also clearly demonstrated that it was not possible to prevent a launched electron from being launched, validating the self-consistency principle. Since then the experiment has been repeated numerous times, always with the same result. Time travel (at least for a few nanoseconds) is possible, but useless.

It should be noted that stutterwarp allows ships to outrun electromagnetic signals: the *Bayern* famously detected radio noise from pre-Twilight Earth on the furthest leg of its trip. This is not time travel, but enables receiving the same signals again by overtaking them. For example, during ARI's detailled imaging of Supernova 2278 the *Huygens* moved a telescope so that numerous images of the star's final years, collapse, supernova and immediate aftermath (corresponding to a 15 year period of the star's activity) could be taken over the project's two year duration, producing the so far best 4D reconstruction of such an event.