Lightspeed Universe

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by

Gerald David Nordley

In the previous article, "The Graphic Demise of FTL," we showed that because the speed of light is the same regardless of how fast you are moving with respect to its source, faster-than-light travel between stars in this universe is time travel with all its attendant causality problems. For instance, if faster than light signals or trips are exchanged between frames of reference that are separated by enough velocity, or distance, the reply arrives before the message is sent.

None of the theoretical methods of achieving FTL trips (tachyons, warps, wormholes, etc.) avoids these causality problems; one would have to appeal to a predestination of all events for logical consistency within an FTL universe, and even then it would seem strange. Imagine getting an email through an FTL device that starts "You sent >>The quick brown fox, etc....". You then sit down and send "The quick brown fox, etc..." You have to do it because that is what you did. Resistance is futile, the future is fixed. You are a space-time automaton.

If any of these points are still unclear, please consult the previous article, or one of the many good books on the subject. In this article, we shall explore the much-neglected possibilities of interstellar travel in a lightspeed universe that has the potential drama of free will and real contingency.

We'll start with a brief review of some relativistic mechanics. If two observers are moving with respect to each other, each other's distance appears shortened, time slowed, and mass increased by the "Lorentz factor." The Lorentz factor is 1/√(1-v^2) where "v" is the relative velocity in light years per year (or light seconds per second, for that matter). When "v" becomes one (the speed of light) the Lorentz factor become infinite, and the outside universe infinitesimally thin. Table 1 lists some Lorentz factors for a few given relative velocities.

A starship at rest has a "rest mass energy" equal to what would be released by completely converting its entire mass to energy. The minimum energy needed to propel a starship to velocity "v" goes up as that rest mass times the Lorentz factor minus 1.

Star travelers experience no barriers. A relativistic starship can go between stars in as little ship time (often called "proper time") as its propulsion system allows; its apparent velocity is unlimited. The only problem is that the calenders at its destination will show an elapsed time greater than the number of light years the ship has traveled.

Table 1. Lorentz factor and apparent velocity

Rel. Vel. $B = v/c$	Lorentz Factor $1/\sqrt{(1-B^2)}$	Apparent velocity on ship (Star dist.)/(ship time) $B^* = v/c$
0.5	1.15	0.58
0.7	1.40	0.98
0.866	2	1.73
0.986	6	5.91
0.995	10	9.96

So much for the background--what are the consequences? After wrestling with this for some months, I've decided to try the classic dialog method.

Q: If I understand this, for a Lorentz factor of 2, the Kinetic energy we need to give the ship equals what you'd get from converting the whole mass of the ship to energy. That's an awful lot of energy! Doesn't this makes interstellar travel impossible, except maybe by slow generation ships?

A: That was conventional wisdom about 1950--before Von Neumann pointed out the exponential growth possibilities of self-replicating machines.

Nowadays, getting the needed energy seems entirely plausible. Robotic "Von Neumann" machines could build solar power stations from lunar and asteroidal material while also making copies of themselves.

If such a machine built one gigawatt solar power station and one copy of itself each year or so, at the end of the first year, you'd have a couple of Von Neumann machines and a billion-watt solar power station. In twenty years, you'd have a million of them.

In about twenty six years, there would be enough energy available to send a 1000-ton starship up to 87% the speed of light. In 40 years of this exponential growth, there would be enough energy for over ten thousand such missions a year.

If ten kilograms of asteroid or moon stuff are needed for every kilowatt of installed solar power capacity, assuming a density of 2.5 tons per cubic meter, all the material mined in 40 years would form a sphere just over 100 km in radius; say the volume of one large asteroid, or a of couple of new craters in the Moon or Mercury.

This many solar power stations, if formed in an array ten thousand kilometers wide along the the orbit of Venus would stretch something like 30 degrees along the orbit and probably be visible from Earth as a thin silver thread in the morning or evening sky. Of course, in a real future, improvements would continue to be made; the mass per power station would decrease, the time to produce the stations would decrease, and the rate of production would be slowed down to match demand long before this scale of impact would be reached.

By the way, nano technology could be helpful but isn't needed; on this scale, our existing microtechnology and insect like intelligence will do just fine. What's needed is cheaper access to space, smart enough software and development work.

Q. Given that we can get that amount of energy, how can we use it to drive starships to relativistic velocities?

A. That's a topic for another whole article, but among the things that might do the job are antimatter rockets, laser pushed spacecraft, and particle (or pellet) pushed spacecraft. The following leaves a lot out, but should give one a general idea for some plausible starships.

Antimatter rockets are a marginal concept because, as far as we know now, it would take a minimum of 100 to 400 times as much energy to make a kilogram of antimatter as you would get back when you annihilate it. Also, such starships would need need huge and inefficient engines to get the kind of acceleration you want for fast interstellar travel. But, with robotic technology, as propellant is burned off and less thrust is needed, engines could be cannibalized by robots and turned into additional propellant. The engineering needed is breathtaking, but not physically impossible.

Laser-pushed light sails look much better--the starship then doesn't have to carry its propellant nor most of the engine mass. However, light sails have some drawbacks; they are inefficient because the light that pushes light sails is reflected without yielding very much momentum or energy to the spacecraft. Also they would be acceleration-limited because all known reflectors are just slightly imperfect and absorb a tiny fraction of the incident light. That small fraction is enough to vaporize the sails at the very high power levels needed to give light sail craft high acceleration.

Still, as described in Dr. Robert Forward's papers and novels, light sail craft could deliver explorers to the nearby stars within a current human lifetime, not to mention the extended lifetimes we expect in the future.

"Beams" of ordinary matter, instead of light, can push starships more efficiently than lasers. These mass beams could be reflected by a pusher plate, a sail, or a magnetic field. In the last, the incoming pellets would be blasted into clouds of ionized particles as they approach. The velocity of a mass-beam-pushed spacecraft is limited only by the velocity of the last particles that strike it.

Propulsion beams need to reach their spacecraft. With lasers, a single huge lens hundreds of kilometers across would focus the propulsion beam on the spacecraft. With mass beams,the beam could be gently kept on course by pressure from lasers set up along the acceleration path. But a more elegant solution would be for the beam particles to steer themselves to the starship, perhaps using tiny diode lasers as reaction engines. The technology to accelerate single atoms to relativistic velocities has been in hand for decades and extending this technology to particles large enough to steer themselves to a target is an engineering exercise in scaling.

To decelerate at previously visited stars, the destination star port can send out a slow-moving stream of matter, a kind of cosmic runaway truck lane, for incoming starships to reflect. First time visits may need to travel more slowly and use rockets or magnetic sails to slow down. Forward has even suggested focusing laser beams across interstellar distances to be reflected by an annular light sail deceleration stage.

Of course, there may be other possibilities; knowing the basic framework of physics doesn't mean we've found all the possible ways of exploiting that physics.

Q: What would these spacecraft look like?

The actual physical appearance of these spacecraft would, of course, be dominated by the propulsion system. But it is still an area where authors and artists can exercise considerable creativity.

Relativistic antimatter rockets would be monstrously huge at the start of their journey, have huge rear ends, and shrink to bare essentials by journey's end.

Light sail craft would have gossamer sails hundreds of kilometers wide trailing relatively tiny habitats with spiderweb-thin stays and lines.

A mass-beam rider would likely be toroidal in overall geometry with the reflector in the center and habitats and equipment arranged around it in a circle some tens of meters wide. A magnetic mirror version might also include a great outer loop, kilometers in extent, stiffened by the strength of its magnetic field as well as a smaller internal loop with a stronger field to protect the habitat and to control leakage.

Inside, these starships would be designed to support their crews for a decade or so in moderate comfort (including perhaps in some form of cold sleep). For life support for a decade or so of ship time, simply carrying some make-up supplies would require less mass than trying to carry the mass of a completely closed life support system--though most of the water and air would be recycled and some cultivation of plants would be done for recreation, if for no other reason.

Starships may need massive shielding against cosmic rays or not depending on advances in radiation medicine and in superconductors for magnetic force field shields. The ship will also encounter occasional particles of interstellar debris at relativistic speeds. A combination of lasers, magnetic fields and ablative shadow shielding should deflect these occasional gas molecule or ions.

Q: That's interesting, but this slower than light universe still seems too constrained. Where does one find any plot tension?

A: There are all the possibilities of human beings exploring, settling and conducting their lives far from the control of any central authority. By virtue of isolation, any problem they encounter becomes much more important, difficult, and tension-provoking for them. Family separations become more poignant and news from home is more precious.

Q: What about mining other planets, stealing resources, and commercial greed?

A: Commercial greed, on an interstellar scale, is a problem. Robotics and artificial intelligence, while lagging with respect to the hopes of some, are light-years ahead of starship propulsion development. So is genetic engineering. By the time we get around to starships or any kind, "stuff" is going to be literally dirt cheap and hardly worth stealing or even shipping.

One thing, for instance, that almost certainly won't be worth shipping between stars–or fighting over–is that old cliche, heavy metals. In space "heavy" is a disadvantage. Anyway, it takes much less energy to refine the tiny amount of heavy elements one needs for modern composite structural material and computer chips from local moon stuff or asteroid material--or, on Earth, to distill the desired elements out of seawater--than to raid some other star system for them.

Another non-starter is rare new elements. All the non-radioactive spots on the periodic table are filled--the only place to add anything is on the end--and what physicists consider "stable" out there is stuff that’s so radioactive that it (fortunately) hangs around for only a few milliseconds.

Biological stuff; spices, drugs, and whatever can be analyzed and the information transmitted to where it is needed. The substances can then be reproduced from local atoms if desired. This would be much less expensive than shipping.

Still, there are unusual things that might be worth interstellar journeys. Authentic originals of great cultural worth (remember "Semly's Necklace" by Ursula Leguin?) might be one example.

But I think the main "cargo" for interstellar journeys will be people.

Q: Earth's history if full of people who went out and conquered others apparently just to conquer. Is this possible on an interstellar scale?

A: Greed for power over others certainly looks like a more viable motivation for interstellar conflict than greed for material things. As far as we know, it is insatiable.

Religious excesses could be a source of conflict. The isolation of interstellar distances might only make this worse--imagine a Jim Jones or a David Koresh with a whole planet! At what point would the rest of humanity feel it had to do do something?

Q: So, if I really wrack my brains a bit for a believable motive, interstellar conflict is still possible. But it's kind of hard to wage an exciting war without warp drive, isn't it?

A: With sufficient thought, effort and creativity, unfortunately not. Joe Haldeman's "Forever War" and Niven and Pournelle's "Footfall" come to mind.

Clearly, any interstellar war fleet is going to be on its own--no calling back to "Starfleet Command" for instructions. Nor does it seem feasible to call for reinforcements that take decades to get there. (But remember those Japanese soldiers hiding out on islands for decades?)

It takes perseverance to conduct a "forever war," but I'm afraid that isn't impossible. One does not have to look too far back in history to find things like crusades, the hundred years war, the punic wars, and the Trojan war in the era of slow communications on Earth. These wars were fought on an almost interstellar time scale. Military forces went somewhere, lived off the land, won or lost there, and some came home. We're still the same species. How long have the Palestinians and Israelis been going at it? It may help writers to think on a Homeric time scale. Interstellar war, if it happens, isn't going to be replay of World War II, nor Tralfalgar, nor Agincourt. But there may be possibilities in Troy.

Another thing to remember is that the greatest drama in war is local and individual. The most dramatic conflict is local, personal, and can't be resolved by blowing everything up. How many stories have you read that invoke FTL and then have to turn around and strain plausibility to isolate their actors from the resources and control FTL implies? Keeping to lightspeed automatically gives you the isolated circumstances, limited resources, and demand on local initiative and creativity that good drama requires.

War has been called "diplomacy by other means." If the spacepower issue is settled in favor of the invaders, there will remain the problem of trying to persuade inhabitants of a planet or inside a space colony to lead their lives differently. At that point, the interstellar aspects of the war recede to distant background.

Q: How would sticking to the speed of light affect strategy and tactics?

A: The Lightspeed limitation also levels the playing field by limiting the resources of the attacking party; initially, the home team has a tremendous logistical advantage.

But one should note here, as Joan Vinge and Larry Niven have, that any propulsion system with interstellar capabilities is also a lethal weapon. A mass moving at a Lorentz Factor of 2 may as well be made out of antimatter; if stopped suddenly (a neat trick, by the way) it would liberate roughly a thousand times as much energy as the explosion of an equal mass of plutonium at rest.

Starships probably make poor fighting ships--too lightweight, too fragile. But once the starships arrive surreptitiously in the outer reaches of a planetary system, they could use a mass from passing Oort cloud objects to make more appropriate equipment. While small with respect to interstellar distances, a planetary system is a huge volume to try to defend.

In space (and probably in the air in not too many years), combat will be robot versus robot with no place for fragile and slow biological beings other than for policy decisions--and those will certainly be computer-aided as well. However, the lightspeed limitation provides an excuse for having at least some people reasonably close to the action to make those policy decisions.

Without FTL systems, random evasive action would be effective. Maneuvering vehicles not be followed by beamed weapons due to lightspeed time lag. 300 km is a light-millisecond, and, in computerized combat, two milliseconds will be a lot of time.

Dealing with this time lag may prove difficult for some authors who dislike math. One way to handle this is to construct a three dimensional model of your battle, with a distance scale of say, one light-millisecond per centimeter. Then simply measure the distance between spacecraft to get the one-way time lag in milliseconds.

Q: Who would the enemy be?

A: Other humans, once we've been out there long enough. Anyone else we encounter is likely to be hundreds of millions of years more experienced than we are both technologically and ethically. Even if we set the issue of ethical evolution aside for the sake of pleasing a luddite market for mayhem, alien enemies are extraordinarily unlikely. Even more unlikely would be alien enemies we could beat.

Q: War has been called "diplomacy by other means." This leads one to think of exerting political power over interstellar distances conjures up the thought of interstellar empires. But how can an emperor control an empire when it takes decades to get any feedback on his decrees?

A: One way would be to use well chosen (and/or well-programmed or well-genetically engineered) viceroys and a timeless appeal to human heritage. An imperial tyranny seems pretty unlikely--the feedback would take too long to satisfy the drives of your usual tyrant. But consider a near legendary emperor to whom everyone pays homage as a symbol of where they came from? Establishing such a figurehead would be a very human thing to do, especially when genetic engineering might be available to ensure that the chosen human had the right innate character for the job, and live long enough (and/or want to stay in the job long enough) to interact with at least the nearer parts of the empire.

A loose interstellar empire make more sense than trying to run an interstellar democracy. I don't like the word "impossible," but elections spread over thousands of years presents a truly mind-boggling scenario. A hereditary constitutional monarchy, on the other hand, handles succession and the maintenance of a symbolic, traditional, identity fairly easily without requiring distant feedback.

The necessary separation of the viceroys from the emperor and from each other leaves room for a more variation in a common imperial theme than a tight FTL-knit empire would allow. Still, the neighboring viceroy might be available for reinforcements if something unpleasant pops up.

As far as cohesion is concerned, it might even be easier to maintain loyalty to an emperor who can't, by virtue of distance, screw things up royally. Also, there may be more senior folk out there who expect us to mind our manners and are fully capable of supplying whatever discipline the leadership of the human race might fail to provide.

There's a certain far-flung majesty to the concept. One could imagine cultural "shells" around Earth, defined by the latest trend emanating from the home planet. The culture two thousand light years away, on the other side of the empire, might thus be more similar to yours than the one only fifty lightyears inward or outward, depending on when the news of a given change reached you.

Hey, that's enough for dozens of novels--I'm going to save some for myself!