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Interstellar

The sun will explode. There is a near infinite universe that is seemingly out of reach to humans forever. God seems to have placed the shining universes and stars of the infinite abyss simply to be observed and fantasized about. Not only would it help with the development of science exponentially, the exploration and habitation of other planets will, in billions of years, be necessary for human life. But is it even possible? Neil Degrasse Tyson, famous astrophysicist, says that, “The only things standing between us and interstellar travel are politics and money—and the need to travel at the speed of light.” Of course, interstellar travel has been the key concept of sci-fi media since the old *Star Trek,* making it easy to visualize just how useful, and also incredible, interstellar travel would be.

There are a few important reasons why I cannot get up and walk to the Andromeda Galaxy right now. The biggest two being gravity and a human’s need for the six fundamental necessities for life. We solve for these two issues using spacecrafts, which can break free of earth’s gravitational pull and keep a fragile human stored up and safe inside his cozy little cockpit. And the use of vehicles then opens up a wonderful world of physics factors that I get to explore.

My mission when beginning my exploration of this topic was to find and push the known limits of engineering. I first searched to find out why sports cars can’t go faster than 300 miles per hour on straight roads. Turns out, the main factor is wind resistance. Therefore, if we want to go really fast, we need to get out to space, where there is no wind resistance. However, when you're out in space, you need mass to move your rocket, since you don't have friction and gravity working on your wheels to propel you forward. A significant amount of mass being exhausted from the engines of the ships means you need a significant amount of fuel. Fuel, unfortunately, is mass, and therefore limited. We therefore cannot go infinitely far in space. This then brought me to the main question that I want to answer. How far can we go in space?

When doing research, you will quickly realize that the answer isn't simple, as you would expect. Currently, space travel is not a major focus of humanity, and apart from a couple well known billionaires, no one is really trying. The research in the field of the limitations of space travel is therefore more theoretical than it is evidence-based. When talking theoretically, you need to set up parameters for exactly what you are trying to solve. I want to know how far a man (who is still alive, not just a dead corpse floating on) can go in space. It can be any vehicle with any fuel source. It does not have to have a return flight. It can use any means necessary, or any number of resources or spacecraft it needs. If we consider an *Interstellar*-esque scenario in which earth is deemed uninhabitable and therefore humanity must leave or die, we have a scenario in which all resources on earth will be devoted to space travel. But if we don't know what our limits are, we won't know how to use our resources or how to get to a new, habitable planet.

It would be near impossible to actually measure an exact distance that we could theoretically travel. The end goal of the "farthest possible travel" would be to travel infinitely. I will be exploring why we can or cannot travel infinitely in space, and why. I will be arguing that there is a physical limit to the extent of human expansion that is built into the physics of space and time. However, theoretical possibilities and the changing nature of science could provide a more optimistic view. There seems to be a God-imposed limit on how far we can go and how fast we can go. This limit is known as something called the laws of physics. Einstein's theory of relativity shows us that we cannot go faster than or go the speed of light, but can only get incrementally closer to it. We can only go so fast, carry so much fuel, and the human body can only withstand so much. However, as we work to find more means of travel, more sources of fuel, and more powerful and efficient rockets, we could eventually work up to a rocket that could go a certain, unknown, probably impressive distance. But what if we question scientific fact? Science has been proven to not be perfect, and disproving the theory of relativity or finding some source of energy or fuel that is infinite or renewable would open a brobdingnagian amount of new doors of possibility.

I do not enjoy being a pessimist, so I will also explore just how much we may be able to do with space travel. My thesis statement suggests that there is a limit. I believe that this limit lies in the difficulty of interstellar travel especially. Interstellar travel is defined by space.com as, "...the ability to travel between stars in the exploration of space." In science fiction, this is often depicted as faster-than-light travel, as this writer goes on to explain. This is where my three major problems come into play. The first is that there is a God-imposed limit on technology and physics. To suggest no limit would be to suggest there's no further you can go. To suggest there is no further in which you can go would suggest that we have reached the edge. Therefore to suggest no limit would suggest we have reached the edge. This is impossible if you believe that the universe is constantly expanding. The universe has a head start on us. And the largest roadblock of them all is our inability to go faster than the speed of light.

The second main problem is this; present technologies do not reveal interstellar travel as a possibility. A manned rocket has never made it to a planet farther than the moon. There's only a certain amount of fuel you can carry in a rocket at once without it being too heavy. Mass (in the form of solid rocket fuels) is needed to move the mass of the rocket. As you carry more fuel, more fuel needs to be pushed out and burned at once to move the rocket at a relative speed. However, according to Tsiolkovsky's rocket equation, or the ideal rocket equation, we can find that even a much lighter, unmanned, rocket such as the Lunar Module from the Apollo missions, with a mass of 15,000 kg, actually gets slightly faster and faster the more fuel you store. Unfortunately, if we used the approximate mass of our entire universe as fuel, we still can only go 2% the speed of light.

The third and final problem with manned space travel I will address is that space travel for humans is too hazardous to withstand and succeed in interstellar space travel. NASA outlines 5 hazards of spaceflight to humans, all of whose effects will be more exaggerated the farther you go. It is also easy to calculate that the velocity necessary to theoretically build toward light speed would immediately kill any passenger. A slower velocity would mean a flight that takes longer than the length of a human life.

The first problem I will address is the problems of the normative laws of physics and reality. My favorite issue with infinite space travel is the theoretical impossibility of faster-than-light travel, which is necessary to reach the edge of the expanding universe. Why is it necessary? How fast is the universe expanding, and how do we know this? A common phrase is that the universe is expanding faster than the speed of light, but physicist Leo C. Stein pushes back on this, clarifying that,

> The premise of the question is confused. The expansion of spacetime is not measured in the same units as the speed of light—the two are simply in different sets of units: The speed of light is measured in units of velocity, which are m/s in conventional units.
>
> The expansion of the universe is measured by the Hubble parameter, which has units of 1/time. Astronomers typically quote the Hubble parameter *today* (and many incorrectly call it the Hubble "constant", but it is not constant), and give it in units of ~70 km/s/Mpc. km and Mpc are both units of length, so this really has units of 1/time. People keep perpetuating this quote of the universe "expanding faster than the speed of light", but it doesn't make sense to compare

those two quantities. It would be an interesting historical exercise to track down the origin of this quote.

The most meaning I can attribute to this quote is as follows. Remember in Hubble's law that *apparent* recession velocity is proportional to distance between two objects (this gets modified for cosmological distances). At any given time in the universe, you can find a distance (c/H) where the apparent recession velocity is the speed of light. Beyond that distance, objects appear to recede faster than the speed of light. But remember, apparent recession velocity is not a real physical velocity!

Basically, the universe is expanding in a way which pulls heavenly bodies apart, and the speed at which it does this is accelerating. This expansion cannot be measured in physical properties such as velocity, but must be defined by Hubble's law. Hubble's law basically shows that galaxies are moving away from earth at speeds relative to their distance from earth. This would mean that the farther it gets away from earth, the faster it moves away.

The next thing to discuss is why the universe is expanding and how we know. This explanation covers the intriguing and dauntingly named dark matter. An excerpt from NASA explains the relationship between dark energy and the expansion of the universe well,

In the early 1990s, one thing was fairly certain about the expansion of the universe. It might have enough energy density to stop its expansion and recollapse, it might have so little energy density that it would never stop expanding, but gravity was certain to slow the expansion as time went on. Granted, the slowing had not been observed, but, theoretically, the universe had to slow. The universe is full of matter and the attractive force of gravity pulls all matter together. Then came 1998 and the Hubble Space Telescope (HST) observations of very distant supernovae that showed that, a long time ago, the universe was actually expanding more slowly than it is today. So the expansion of the universe has not been slowing due to gravity, as everyone thought, it has been accelerating. No one expected this, no one knew how to explain it. But something was causing it.

Eventually theorists came up with three sorts of explanations. Maybe it was a result of a long-discarded version of Einstein's theory of gravity, one that contained what was called a "cosmological constant." Maybe there was some strange kind of energy-fluid that filled space. Maybe there is something wrong with Einstein's theory of gravity and a new theory could include some kind of field that creates this cosmic acceleration. Theorists still don't know what the correct explanation is, but they have given the solution a name. It is called dark energy.

Dark energy is a mysterious energy that is said to fill up about 68% of the universe. Little is known about dark energy. It is a property of space used to describe the unexplainable constant expansion of space. Einstein was the first to theorize that empty space can possess its own energy. More is known about what dark energy isn't than what it is, which makes it more of a placeholder used as a cop-out answer to the question of why the universe expands.

NASA seems to be confused with how the universe expands, so how did we even come up with the theory that it does expand? Hubble has been mentioned a couple times, and it is because of him and his telescope that we have evidence of the universe expanding. Hubblesite.org, a website dedicated to him, explains it well, "In 1929, Edwin Hubble provided the first observational evidence for the universe having a finite age. Using the largest telescope of the time, he discovered that the more distant a galaxy is from us, the faster it appears to be receding into space. This means that the universe is expanding uniformly in all directions."

Since the universe is in fact expanding, and the distance between us and the edge of the universe is progressing faster than one light year per year, we would need to move faster than light to reach limitless travel. Einstein and his theory of relativity say this isn't possible.

Albert Einstein was a very well known German-born physicist. His theory of relativity was probably his most well known work. While its veritability is still speculated among more skeptical physicists of today, it is a widely used, extremely helpful theory that claims a lot of useful things about how light works. But what is it exactly? Einstein's theory of relativity is the way that Einstein understood how gravity affects the universe. An article from Space.com visualizes it well, explaining that, "As he worked out the equations for his general theory of relativity, Einstein realized that massive objects caused a distortion in space-time. Imagine setting a large object in the center of a trampoline. The object would press down into the fabric, causing it to dimple. If you then attempt to roll a marble around the edge of the trampoline, the marble would spiral inward toward the body, pulled in much the same way that the gravity of a planet pulls at rocks in space." This is basically demonstrating that the massiveness of an object has a certain quantifiable pull on the space around it, which is a force that an English physicist named Isaac Newton coined as "gravity". But how does this affect moving fast? Well, as I stated earlier, one of the deductions from his theory was that faster-than-light travel isn't possible in a vacuum. This is because the faster an object travels, the more massive it becomes. An accelerating object gains mass and therefore becomes heavier. It then takes more and more energy to accelerate. It would take an infinite amount of energy to make an object reach the speed of light. Light is a universally constant speed limit. It is defined as the speed at which light, which is weightless, travels (300000 km/s). Anything that has any quantifiable mass would take an infinite amount of energy in order to accelerate it to this weightless state of speed. Therefore, faster than light travel isn't theoretically possible to anything with mass.

If you are to suggest limitless travel, you would need to have a reachable edge of the universe, and a viable means of travel to this edge. Our current understanding of the physics of the universe either suggests no edge, or an edge which is expanding too quickly for humans to reach. There is also no possible way to make any massive object travel fast enough no matter how slim you try to make it or what fuel you think to use. Limitless travel is therefore impossible.

Looking at our current rockets definitely don't make infinite travel seem more likely. Scientists throughout the years have been able to do impressive things with space travel, rockets, the International Space Station, and astrophysics in general, and the improvement of technology sometimes seems exponential. There are a lot of great things about our current understanding of space travel. Elon Musk and NASA have both promised human visits to Mars in the "near" future. Unfortunately, my task of infinite travel is much too ambitious for anyone currently to even consider. So this begs the question, where are we with our speedy things and what's stopping us from going faster?

Well, rockets work similar to a car's combustion engine, except for the lack of oxygen and gravity, which are both complete necessities for a car. You see, in order to solve the lack of oxygen, a rocket will carry a chemical that can react in the thruster similar to oxygen. This aspect is called the oxidant. NASA themselves explain this similarly, explaining,"In a rocket engine, fuel and a source of oxygen, called an oxidizer, are mixed and exploded in a combustion chamber. The combustion produces hot exhaust which is passed through a nozzle to accelerate the flow and produce thrust. For a rocket, the accelerated gas, or working fluid, is the hot exhaust produced during combustion. This is a different working fluid than you find in a turbine engine or propeller powered aircraft. Turbine engines and propellers use air from the atmosphere as the working fluid, but rockets use the combustion exhaust gases. In outer space there is no atmosphere so turbines and propellers can not work there. This explains why a rocket works in space but a turbine engine or a propeller does not work." Cars use wheels, and this works because while gravity is keeping the car on the road, the wheels are transmitting the force they receive from the powertrain (which receives its force from the engine) into tractive force from the tires to the road. A propeller's engine powers a propeller, which uses air from the atmosphere to propel it forward. Southernwings.co.nz explains it in an article, saying," The propeller works by displacing the air pulling it behind itself (the action), this movement of air then results in the aircraft being pushed forward from the resulting pressure difference (the opposite reaction). The more air that is pulled behind the propeller the more thrust or forward propulsion is generated.``

A rocket works similarly, but needs to solve for the lack of external forces to help it move. The way in which a rocket is able to move is because of its thrusters. The engine is able to take its fuel and oxidizer and burn it into an exhaust. But the exhaust of a rocket does more than just pollute the air. Newton's third law comes into play.

Newton's third law was that for every action, there is an equal and opposite reaction. The reaction of massive exhaust from a thruster being rapidly thrown down from the rocket is the rocket moving in the opposite direction. This is the principle that gives a rocket its ability to propel even in a vacuum with no atmosphere or gravity. The exhausted fuel from the thrusters continually push the rocket faster and faster for as long as the rocket can until it cannot hold any more fuel. And at that point, the lack of gravity and air resistance especially becomes a huge advantage, as the speed of the rocket builds. With no air resistance or gravity to fight against the push of the rocket, the rocket becomes faster and faster the more it is pushed.

When driving up a hill with a car, you will find that in order to travel the same speed you need to give the car more and more gas, which basically means your wheels need more and more torque and force in order to fight against the elevated effects of gravity on the car. Even when you are driving straight, your car cannot go as fast as a rocket because it is fighting against air and gravity. 763.035mph is the fastest a car has ever gone. This was the ThrustSSC. It is nothing like a typical car, but its creators still had to solve for wind resistance and wheel acceleration. Anyone who has ever worked with cars and aerodynamics, like the makers of the ThrustSSC, will be the first to tell you that the number one problem with speed in a vehicle is wind resistance.

With a rocket, once it breaks free of earth's atmosphere, it is in the vacuum of space, meaning no air resistance, meaning with infinite fuel you could theoretically go infinitely fast. So what aspects exactly are limiting our rocket speeds in 2023? Forbes explains that,"Right now, there are only three things limiting how far our spacecrafts can take us in the Universe: the resources we devote to it, the constraints of our existing technology, and the laws of physics." As I said earlier, let's assume a time where all of earth's efforts are put into space travel. In an apocalyptic event like the impending supernova of the sun, would we be able to do anything?

Luckily for me, there are an abundance of equations necessary to solve for a best-case scenario space launch of a rocket, and an astrophysicist named Jack Frasier-Govi has helped me greatly with this calculation. The Tsiolkovsky rocket equation is an equation which is used to judge the speed of a rocket that carries its own fuel. It can be simplified as $\Delta v = I_{sp} \ln(m_0 / m_1)$ Where Δv is change in velocity burning fuel with a specific impulse I_{sp}, which reduces the mass of the rocket from m_0 to m_1. However, since we are going for maximum velocity, we will use the relativistic version, in case we are able to reach the speed of light. This equation is $\Delta V_{relativistic} = c \tanh(I_{sp}/c \ln(m_0/m_1))$ Now, with this equation, we are going to strongman our current technologies and use the weight of only the lunar module from the Apollo missions as our rocket and assume it can hold massive amounts of fuel with the same fuel tank.

A chemical rocket has a maximum specific impulse of around 5000ms^{-1} (meters per second), and this specific rocket weighs about 15,000 kg. Fundamentally, you are limited by the amount of fuel you are able to store and give your vehicle. If you give yourself just as much fuel mass as your rocket weighs, you are able to reach 3465.7ms^{-1}, which isn't nearly fast enough for our purposes. It doesn't even reach escape velocity (11,184 m/s). If you give yourself 10x the weight of the payload (weight of the module) , you can reach 11989.5 ms^{-1}, which means we made it to escape velocity, but not much further. If you give yourself 10000x the weight of the payload, you can reach 46052ms^{-1}, but that's only four times as fast as 10x. If we give it all the fuel from all oil reserves on the planet, we can reach 116096ms^{-1}. How close is that to the speed of light? Well, we've made it all the way to 0.038% the speed of light. If we are able to turn all the mass of earth into fuel, we can reach 237122ms^{-1}. How close did we get this time? Still less than 0.1% there, which is discouraging. If we chuck the entire solar system, including the sun, into our fuel tank as fuel, we can reach 300774ms^{-1}. Did we make it? We were close, with a whopping 0.1%. If we turn the estimated mass of the entire universe into fuel, we can reach 562105ms^{-1}.And by using the entire realm of physical atoms in the fuel tank of a 15000 kg space exploration module, we were able to reach a whopping 0.2% the speed of light. It’s not looking optimistic for any rocket to go anywhere near as fast, especially not one with a person inside.

The topic of the influence of a rocket being manned brings me to my third and final main point. Space travel for humans is too hazardous to withstand and succeed in interstellar space travel. Interstellar space travel for humans, as outlined by NASA, has five large hazards. The first of these being radiation. Space radiation is invisible to the human eye. Not only is it impossible to spot and near impossible to detect, it is fatally dangerous. Radiation is considered the most menacing of the five. Radiation exposure damages the central nervous system, harms cognitive function, reduces motor function and prompts behavioral changes. It also greatly raises the chances of cancer. The space station sits just within Earth’s protective magnetic field. While they still have 10x the exposure of us ground-dwellers, It’s nothing compared to deep space.

The second hazard is one that has been a hazard to people on the ground in certain scenarios, which make the effects very obvious and real. The second hazard is isolation and confinement. If you’ve ever been isolated or seen someone who has been severely isolated in a small space or has had minimal human interaction, you know that, simply put, things can get weird. People who have been alone or confined for too long can show signs of insanity and aggression, and anxiety and depression can come very quickly into this journey. Astronauts are even more isolated than any of us can imagine being.

The third and most obvious is distance from earth. Mars is about 140 million miles from earth. Astronauts traveling to mars would be leaving our planet for roughly three years. If a medical event or emergence happens while a journey is underway, they can't call 911, no ambulance is coming, and no paramedics are going to be there to administer CPR. It's simply game over.

The fourth problem is the lack of gravity. NASA states in their outline of the hazards that,"The variance of gravity that astronauts will encounter is the fourth hazard of a human mission. On Mars, astronauts would need to live and work in three-eighths of Earth's gravitational pull for up to two years. Additionally, on the six-month trek between the planets, explorers will experience total weightlessness." This hazard would mainly apply to the visitation of any planet with a different gravitational pull than earths, but the lack of gravity in the cab of a rocket on a long trip would also need to be adjusted in order to avoid losing bone density and skeletal muscle deterioration issues.

The fifth and final hazard is hostile/closed environments. A spacecraft is not only a machine, it needs to be your home. The ecosystem inside the vehicle would play a role in everyday astronaut life, and keeping important habitability factors up to code, like temperature, pressure, lighting, noise, and quantity of space. It is also essential that astronauts are getting the requisite food, sleep, and exercise needed to stay healthy and happy. Any failure in these areas can be fatal, and maintaining all of these factors can be difficult, grueling, and tedious.

The laws of space and limitations of technology seem to directly point to the fact that a journey to the end of the universe is absurd. However, is there anything or anyone that would say otherwise? One thing scientists turn to when thinking of the potential future of interstellar travel is nuclear fusion. Bmisis.org details it this way," Nuclear fusion has been recognised for some time, it is the process that occurs in the core of the Sun and other stars as the incredibly high temperatures achieved as a result of immense gravitational pressure causes small atoms such as hydrogen to fuse together and form helium and larger atoms, releasing energy in the process." Wait a minute, it happens in stars? And it releases more energy than any fuel source ever harnessed? What if we are a million years into the future, science has grown exponentially, Einstein now obsolete, and we are able to build a rocket that can harvest stars and perform nuclear fusion for eternity, constantly building speed for as long as it takes until we get to the edge of the universe? This would be a possibility if it wasn't impossible. Not only am I unwilling to assume a world where Einstein's relativity is out the window, there is no conceivable way that a human could or would be able to remain in a living apparatus long enough for this to happen. Any alternative fuel or energy source that we may find in the future will be exquisitely useful for new and better rockets, but suggesting that these rockets have infinite potential is impossible.

Putting aside the logistics of making a rocket like this, the other problem that I find is that the God-imposed laws of physics and the constantly expanding universe seem to me to point to a God-imposed limit on human exploration. We have purpose in God beyond our comprehension and we are infinitely loved and important and will one day be in the infinite joy of God. We, however, have better things to do than send out a couple people to meet their demise at the dark edge of the universe, believe it or not. Although the beauty and wonder of space has been proven to point people to God, it is not our purpose for living.

One thing that is needed to be avoided is a wholly pessimistic attitude towards interstellar travel. The world of astrophysics is one that is beautiful and exciting to explore, and is a useful realm of study. One could say, then, that in my paper, which specifically searches to limit a scientific possibility, science is unnecessarily limited. To limit scientific prediction is to limit science, and the reliability of the scientific method and current scientific fact is always under debate. There are many examples of paradigm shifts in the world of science, most notably the shift from heliocentric to geocentric when talking about models of the solar system. There are articles from NASA themself questioning the truth and limits given by the theory of relativity. Why, then, is it ok to go out of your way to limit science when we do not know the full picture?

Purpose is a question that comes into play with everything. As I noted, God doesn't seem to have put us in a position where exploring the ends of the galaxy is within our purpose as humans. I would also refer back to my point about how the universe either has no edge, or its edge is expanding at a rate that is uncoincidentally fast enough that it is never reached by any particle at any distance away from it ever. Some things, like the edge of the universe and the speed of light, are things that are built into the fabric of the universe by intelligent design.

All of this, then, was for the purpose of establishing our limits of travel in the universe. The world of engineering and astrophysics is one that is and should have many resources devoted to it. Speed will always be one of the more exciting human endeavors. I have shown you why and how God has put limits on our physics, how it is scientifically proven we are unable to get a rocket anywhere near fast enough, and how our bodies are not made to go to the ends of the universe. Instead, God has given us purpose on this earth and in this solar system, to reach the ends of this planet with his word and to continue to reflect him in all that we do, whether we are building rockets or building his kingdom. Thank you.

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