Space Travel to the Edge of the Universe in Just 44 Years

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This Article proposes that, with a spacecraft capable of constant 1g acceleration, humans could theoretically travel anywhere in the observable universe within a single lifetime. Time dilation from Einstein's relativity would make long interstellar journeys feel much shorter for travelers than for people on Earth. Trips to nearby star systems like Proxima Centauri b could take just a few years, while even journeys to the edge of the observable universe could take only approximately 44 years for the crew. Achieving this will require revolutionary advances in propulsion, energy, life support, and radiation protection. Considering space travelling most likely will be humanity's only option for survival in the distant future, this article focuses on the basic physics relevant for that path.

Nomenclature

g	=	G-force
EJ	=	Exajoules

I. Abstract

THEORETICALLY, any place in the observable universe could be visited within a human lifetime, given sufficiently advanced propulsion technology. This paper explores how relativistic physics allows surprisingly short travel times for travelers aboard a hypothetical spacecraft capable of constant 1g acceleration. Time dilation, acceleration profiles, and energy requirements are analyzed for destinations ranging from Proxima Centauri b to the farthest observable galaxies. The practical challenges of propulsion, life support, radiation shielding, and artificial gravity are also discussed.

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II. Introduction

Humanity has long looked to the stars, imagining interstellar travel as unreachable. However, known relativistic physics predicts that journeys to distant star systems could be completed within a human lifetime if constant 1g acceleration is achievable. This paper investigates these theoretical missions, focusing on travel time, energy requirements, and the technological challenges involved.

III. Relativistic Travel Principles

Since matter cannot reach the speed of light, the spacecraft is assumed to accelerate up to 99.9999999999% of c, then flip at the halfway point and decelerate at 1g to reach the destination smoothly. Average rockets generate 3g; Mercury astronauts experienced up to 8g during launch.

Einstein's relativity is experimentally validated by GPS satellites, where time dilation must be corrected for satellite clocks to remain synchronized with Earth clocks. Travelers moving near-light speeds experience significant time dilation relative to Earth observers.

IV. Time Travel Examples

Proxima Centauri b is the nearest Earth like planet in our neighboring galaxy 4.24 light years away. If the prescribed spaceship travelled from Earth to Proxima Centauri b, it would have to accelerate with 1g until it reaches 95.1% of the speed of light when it needs to flip and decelerate with 1g to arrive smoothly at Proxima Centauri b. For the travelers, the trip will last 3.5 years according to the spaceship clock while 5 years and 10 months have passed on Earth.

While 3.5 years sound very acceptable for a trip to a planet 4.24 light years (5.9 trillion miles) away, Proxima Centauri b is almost too close to take advantage of the relativity theory.

Trappist-1 System is about 40 light years away and is at an ideal distance for our space ship. There are three Earth like planets in that system. Our spaceship would have to accelerate continuously with 1g to 99.999% of the speed of light for 3 years and seven months and then flip and decelerate for the same amount of time with 1g. When it arrives at the Trappist-1 System, 7 years and 2 months have passed for the travelers. On Earth on the other hand, almost 21 years have passed. That means after a round trip, all the people the travelers meet again on Earth aged about 26 years more than the travelers.

The time gap between observers and travelers increases significantly more with destinations farther away. Traveling to a system 3000 light years away from Earth would take 15.3 years for a traveler in our spaceship while 3003 years will have passed on Earth. The traveler would accelerate with 1g for 7.66 years to 99.999997997% of the speed of light before flipping the spaceship around and starting to decelerate with 1g for another 7.66 years. In that scenario communication would be out of question and it surely would be a one way journey.

The farthest galaxies we can observe from Earth are about 13.4 billion light years away. We can't see anything beyond the observable universe. Our spaceship could accelerate with 1g and reach 99.9999999999% of the speed of light in 13.45 years. Then coast for 17.5 years before flipping the engine and decelerating for 13.45 years and reaching any of those farthest systems within "just" 44.4 years of travel time. However, the spaceship would need to create some sort of centrifugal force to provide gravity for the crew during the coasting period of the journey. While travelers have aged only a little more than 44 years during that incredible journey, about 13.5 billion years will have passed for Earth, which means there won't be any Earth remaining since it is expected to be engulfed by the Sun when it expands to a red giant in 7.6 billion years. That would definitely be a one way trip.

V. Technical Challenges

The biggest challenge is to invent the necessary engine technology. Conventional rocket boosters would need to carry a tank of 7.2 trillion gallons of rocket fuel to provide the necessary energy to accelerate a Falcon X size spaceship to 99.9999999999% of the speed of light. That's about 110 million times more than the Falcon X uses to launch into orbital space. In energy units, that's the equivalent of 953 Exajoules (EJ). The total annual global energy consumption of Earth (2024) is ≈600 EJ. Thus, the required energy equals of approximately 1.5 years of Earth's annual energy consumption or 0.17sec of sun's energy output. And we would need the same amount to decelerate down to zero again. Antimatter or fusion propulsion might help close that gap. NASA is currently working on a promising engine called Helical Engine. Theoretically, one would need about 35 million pounds of nitrogen in the tank to produce 953EJ of energy with nuclear fusion of nitrogen nuclei. That amount is equal to 82 Boing 747-8 full fuel tanks or 30 Falcon 9 fuel tanks. It's not too much considering the distance travelling. The big challenge is to transform that energy into thrust.

Avoiding collisions with interstellar dust or objects at near-light speed would require extremely advanced detection and shielding systems.

Food, water, oxygen-generators and recycling systems must last decades in space. Today's systems can supply astronauts about 1-2 years without resupply. With advanced space farming and recycling, missions can most likely last decades.

Gravity. NASA studies have proven that humans cannot live in zero gravity (microgravity) for an extended time without health problems such as bone density loss, fluid shifts, immune system changes, cardiovascular deconditioning and vision problems. Radiation exposure increases cancer and neurological risk independent of microgravity. Thus, the spaceship would need to provide protection against radiation and also provide gravity for the coasting part of the trips. Gravity for the coasting part of travels could be provided with rotating wheel space station designs paired with radiation shielded housings made with hydrogen-rich materials.

Remark: Just because today's generation believes it's an impossible task, it does not necessarily mean it is the case. Two hundred years ago, the general public believed, it's impossible for humans to fly. One hundred years ago, physics-experts stated, its physically impossible to fly higher than 30,000 feet and impossible to travel at a speed higher than 300 miles per hour due to physical limitations. It is very likely scientists will eventually invent engines efficient enough to provide the necessary thrust and efficiency.

VI. Conclusion

Humans can theoretically travel, within a single life time, to any place in the observable universe outside our galaxy between just a few years and up to a maximum travel time of 44.4 years. The spaceship just needs an engine that is capable of providing 1g acceleration between 3 and 27 years. The travel time could be even shortened if the spaceship was going to accelerate faster than 1g. For example 2g while the crew is asleep. The gravitational time dilation would add to velocity-based time dilation.

The price? Energy, engineering, and never seeing Earth again if traveling too far.

While our existence on earth is secure for now, space travelling most likely will be humanity's only option for survival in the distant future — and understanding time dilation and constant acceleration is the first step.

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