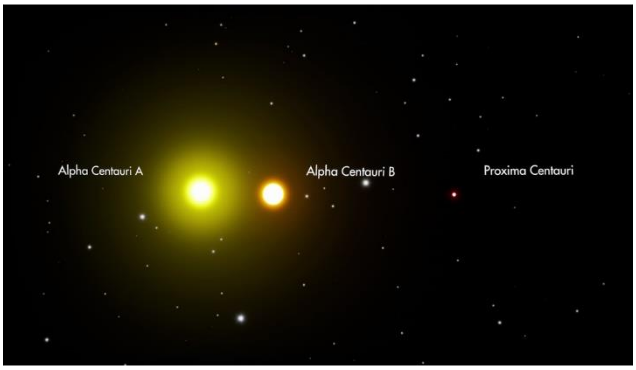
WHY MATTER-ANTIMATTER ENGINES ARE NOT PRACTICAL AND WHY INTERSTELLAR TRAVEL MAY NOT BE POSSIBLE

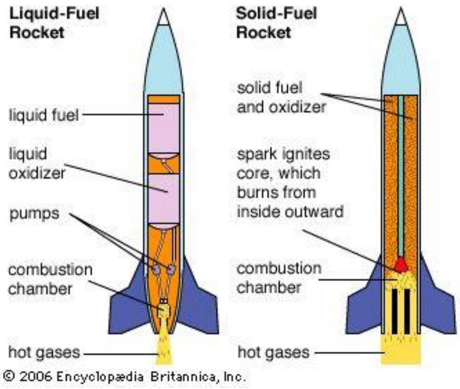
The stars have always fascinated us, these cosmic nuclear reactors are the fundamental energy source for any civilization. As we progress in our scouting of the solar system, it is time we think about going outside the crib that has held us this long. Going interstellar is no menial task, manned missions to even the closest star systems requires vast technological leaps from where we stand, we have yet to figure out an efficient starship fuel, for manned missions, there is a challenge of how the crew would be preserved for the long period of the voyage and how the universe seemed to have engineered these vast gaps in, possibly to isolate civilizations (A Fermi Paradox solution) and more. We have sure progressed far from swinging clubs and making stone tools. In 1957, Sputnik 1 mission was the first-time man touched the void of space. In 1969, during apollo 11 was the first-time man had stepped on a cosmic object other than earth. Since then, we have sent various probes and rovers to many planets. We are far from completing the survey of our system, after this is done, there is nothing for humanity but to look to the stars, or maybe not, we'll brief on why that is the case.

INTERSTELLAR TRAVEL IS A HURDLE

The closest star system to Sol (i.e. sun) is located about 4.3 lightyears away and is called the Alpha Centauri system. The system has three stars, Alpha Centauri A, Alpha Centauri B and a smaller star orbiting these, called Proxima Centauri. If you had a ship that could accelerate you to 100% c and deccelerate you in the same way, it would only take you 4.3 years in you relative time to get you there. Practically, this is never the case. You would have to expend fuel to accelerate, then coast for the majority of the trip (because you need to conserve fuel, fuel is expensive) and then expend fuel to deccelerate. With our current method of rocket propulsion (chemical propulsion), even if we maxed out on every aspect of chemical rockets, sending and unmanned probe to Alpha Centauri would take about 6300 years. If we were to talk about manned missions, with all the life support tech and other modules, we are talking about a span closer to 70,000 years. This is obviously not a practical timespand, thousands of years in space is almost certain to be bad. First of all, an unmanned probe would technically get there in 6300 year span but then, it would need electronic instruments that would survive all sorts of cosmic radiations for that amount of time, it would require us to have a mastery of chemical propulsion to even try this and most significant of all, humanity would improve significantly in technology before the probe has even reached Alpha Centauri. If that's the case, what is the point in sending the probe before we are completely capable in the first place?. Scientists are trying to figure out the next form of rocket propulsion, atomic propulsion. These atomic rockets would use uranium-235, uranium-233 and/or Plutonium-239. These provide better mass ratios (ratio of mass of rocket with propellant and fuel to mass of rocket without these) and exhaust velocities (velocity at which prepellant comes out through nozzle) in the Tsiolkovsky rocket equation due to better energy density by nuclear fission or fusion. Even then, it would still take over a thousand years for us to get to Alpha Centauri.(you can read more about the rocket equation here). But looking at our current technology is kind of meaningless as no country or company is planning space missions such as these as of now, these are well beyond our scope right now as we've just seen, it takes a leap in technology to make interstellar travel possible.

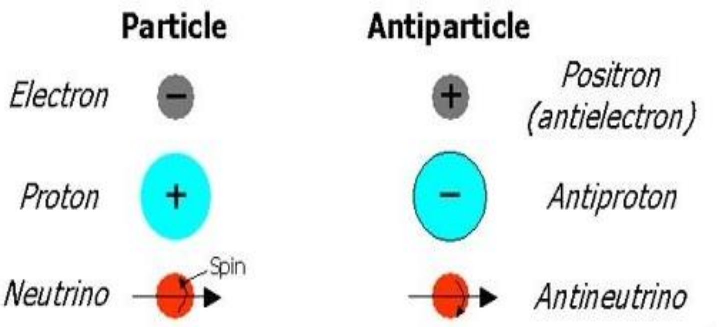


Rockets move through space my expelling mass from the nozzle so that the back reaction would push the rocket forward by Newton's third law. A rocket has a propellant that goes out of the nozzle providing the reaction that pushes the rocket forward, in order to get the propellant out, an oxidizer, or any other fuel is used. The fuel mass heats the propellant which goes out, that's how rockets move. Atomic rockets are possible because they do this. The hypothesized "reactionless drives" that warp spacetime to give very high g's of acceleration are very 'hypothetical', we are nowhere near building one and by some scientists, even thought to be impossible. In order to reach nearby star systems in a practical timespan, we would need a 'Torchship', i.e., a starship that would point in the direction of the target star system, fire up all engines to reach relativistic velocities and after reaching maximum velocity, would begin deccelerating immedeately to get into the orbit of the target star. The problem with this that you can only carry so much fuel mass to heat the propellant. The more mass you carry, the more thrust you need. Conventional chemical rockets will never achieve as high a performance required for interstellar travel, maybe a very efficient atomic rocket can but it would still be hard. Another alternative is a matter-antimatter drive, which uses annihilation to provide thrust to the rocket.



THE PROBLEM WITH ANTIMATTER

At first glance, antimatter might seem to be a very good energy source. Fundamental particles like electrons, protons and neutrons have their antimatter counterparts; positrons, anti-protons and anti-neutrons. When a particle and the analogous anti-particle meet, they annihilate, releasing energy in the form of gamma rays according to Einstein's equation of special relativity. The antimatter counterpart of a given particle has a charge opposite to to it (eg: an electron has a negative charge while a positron has a positive charge) and also has an opposite spin, In the case of neutrons that don't have a charge, an anti-neutron doesn't have a charge but has an opposite spin, same with the case of chargeless neutrinos. Essentially, and antiparticle looks like the mirror image of a particle. By special relativity, $E = mc^2$ and by this, 1 kg of matter annihilates with 1 kg of antimatter to give $1.8\text{x}10^{17}$ J or 180 petajoules of energy. This is just less than the yield of the largest thermonuclear weapon ever detonated, the Tsar Bomba.



If this gives the idea that antimatter is a high density energy source, that's not really the case. Yes, antimatter in large quantities would be very efficient and would have tremendously high energy density but the fact that antimatter is much rarer in the universe than normal matter makes the idea of 'antimatter mines' obsolete. We do not know of any place in the universe where antimatter would be available in large quantities suitable for extraction. This means that to use antimatter, we first need to create antimatter, this is a problem. This means that antimatter is not really a source of energy but acts more like a 'battery', antimatter is an energy transfer mechanism, it basically takes in the electrical energy used to produce it and stores it, turning it into gamma rays (which in itself is hard to manipulate and use) and other particles when needed. Even working more like a battery, antimatter does a terrible job. There is a law called the Law of Baryon Number Conservation (more about it here), it basically says that when creating antimatter equal amounts of matter must be created (net charge in the universe should be equalised to zero). This puts the theoretical maximum efficiency of antimatter production a 50%. This means that if you expend 1 million joules to make positrons, you would get 0.5 million joule worth of positrons but physics dictates that the other 0.5 million joules would be spent to create normal electrons. With current particle accelerators, we can create antimatter with a meagre efficiency of 0.000002%. The rest of the energy is lost as heat, which then has to be radiated somehow, causing even more trouble. Now, we are able to produce about a billionth of a gram of antimatter per year, this is nowhere near enough for applications such as space travel. The scope of this can be displayed with calculations (approximations and simplifications are made). For our example, consider a 550 ton (no fuel or propellant mass included) ship accelerating at about 0.45 g s, reaching the maximum velocity of 88% c would need about 3750 tons of antimatter fuel and about the same mass of normal matter (Fuel energy equivalent of $676x10^{21}$ J). The current energy consumption of the entire human race is about 600 exajoules (or $6x10^{20}$ J). This gives us a single trip to alpha centauri at roughly 1125 times the current global energy output. This would get the ship from Sol to Alpha Centauri A in about 5 and a half years relative to the ship's crew (about 7 and a half years relative to earth due to time dilation). This doesn't consider the amount of heat the spaceship needs to radiate per second to keep it from melting (which would require a heat radiator with stupidly high efficiency). About storing antimatter fuel, regular containers cannot be used to store antimatter as the particles and antiparticles would just annahilate. We currently use very intense magnetic fields to store antimatter but for large amounts in the order of tons, this would not be sufficient as a tremendous amount of energy is required to maintain such magnetic fields. Therefore, we have no known methods to store such large amounts of antimatter. Also, improper storage causes a huge safetly hazard as if antimatter ever touched the container, a chain reaction would be initiated and the starship would be vaporised. Even if we solved all these problems, there would be the issue of sustaining life for the said 5 and a half years on a starship. It is known that humans do not work well in isolated situations in long timespans, it has too many unknown variables. The so called 'generation ships' are not practical and also has too many unknown variables. One alternative to these is cryogenic sleep, on which developments are going on. This will help any manned mission, not only interstellar travel but the perfection of cryogenic sleep would never make interstellar travel possible.

In retrospect, we are nowhere near using antimatter as fuel for our space missions, we do not have the practical capability to create large amounts of antimatter nor store it. Thus, the conclusion is that chemical rockets, atomic rockets and antimatter rockets are not workable enough to cover interstellar distances to reach other star systems and reactionless drives are nothing but a hyopthsis. Maybe if humanity pour all their efforts into an interstellar space mission for a long period of time, it may be possible in the far future but why would we? What is the use in spending all that energy and effort if it was simply just to visit another star system for the sake of it? What do we gain from it? What if we don't find anything useful there? Those are gambles no one dares to take. It seems that there either isn't a practical way to reach other star systems or that such a way requires enormous technological leaps to achieve and master. This in itself is a solution of the fermi paradox, which is a lack of intelligent alien life observed when we should have seen many such intelligent lifeforms by now. Maybe no civilization has advanced enough to cover these vast distances to reach other star systems, or maybe they never will, maybe interstellar travel doesn't have any solution and that is the way things are. In that case, the only cue we should look for are signals sent by other civilizations, that is the only way of knowing whether other civilizations exist out there. We are not close to knowing whether we are locked inside our home star system. Just remember that no one thought that anyone could split an atom until someone did.