Could we Prolong the Life of our Sun?

Brandon Weigel · Follow
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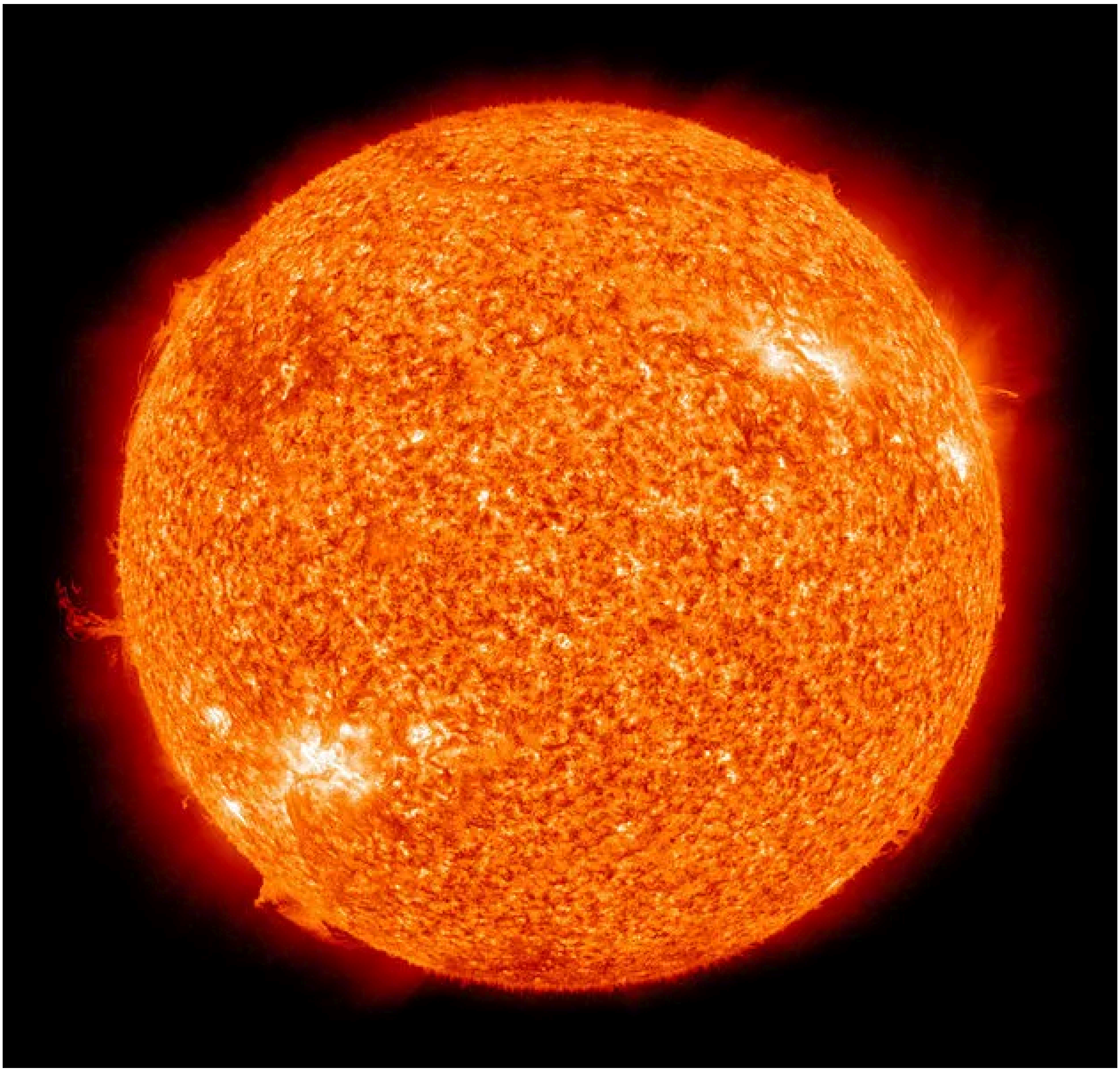


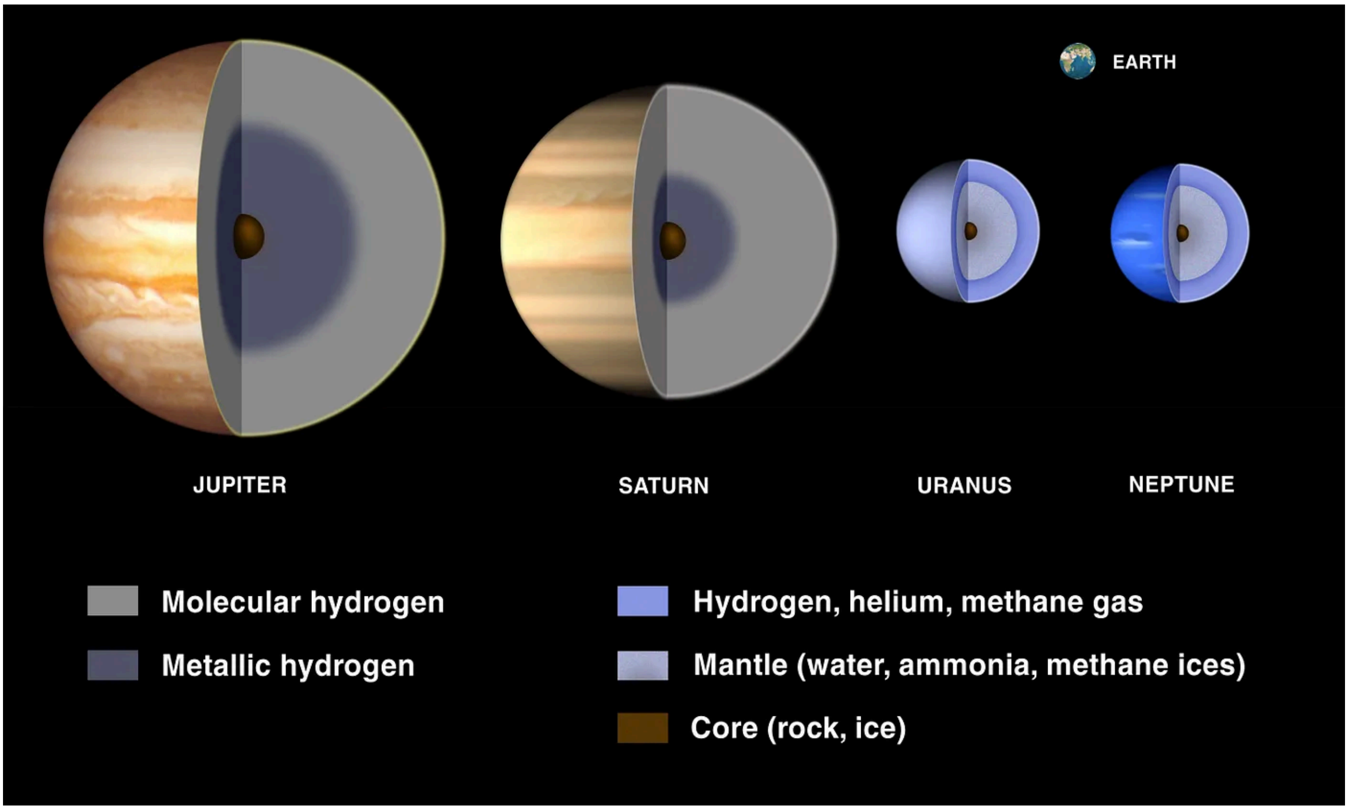
Our beautiful Sun, photographed by NASA's Solar Dynamics Observatory.

Our Sun is running out of fuel. In about a billion years, the centerpiece of our solar system will bloat to a sufficient radius where it will spark a rampant runaway greenhouse effect on our planet, regardless of current anti-CO2 efforts, which will raise Earth's surface temperature above the boiling point of water. If we haven't already either moved away or gone extinct, this event will definitively mark the end of all life on Earth; possibly the only instance of life in our universe. Even if we could find a way to cool the Earth using alternative methods during this phase, the Sun's source of hydrogen is ultimately limited. In an additional 4 billion years our Sun will take its last breath, shedding its remaining atmosphere to expose a dead corpse with about half its current mass and a radius no greater than that of the Earth itself; a white dwarf. If the Earth isn't consumed by the Sun's preceding red giant phase, it will be left a dead, charred world with as much of a chance for life as the Moon has now.

A billion years is a long time, but this isn't a dilemma that can be resolved overnight. One obvious solution would be to advance our race to an interstellar level, pack up our planet, and head to the next star system. Though effective, this solution would only reset the proverbial doomsday clock for the new planet and its parent star, and would require hopping to another new star system every few billion years. Not to mention that transporting an entire planet of life to another planet light-years away would take an astronomical amount of time and energy. In the event that faster-than-light technology isn't allowed by the laws of physics, this solution may turn out to be all together impractical.

We may not be able to escape the ticking time bomb of our own Sun or other stars, but what if there were a way to slow down the timer? If we could prolong the life of our Sun for billions or even trillions of years, we could not only halt the destruction of our home planet, but gain access to a permanent haven as we as a species branch out and explore the universe around us. If Earth is the only example of life in our universe, such a solution may be the only practical means of preserving every relic of that life on our planet for future generations of humans to study and observe. Could we prolong the life of our Sun? Let's take a look.

More Fuel!

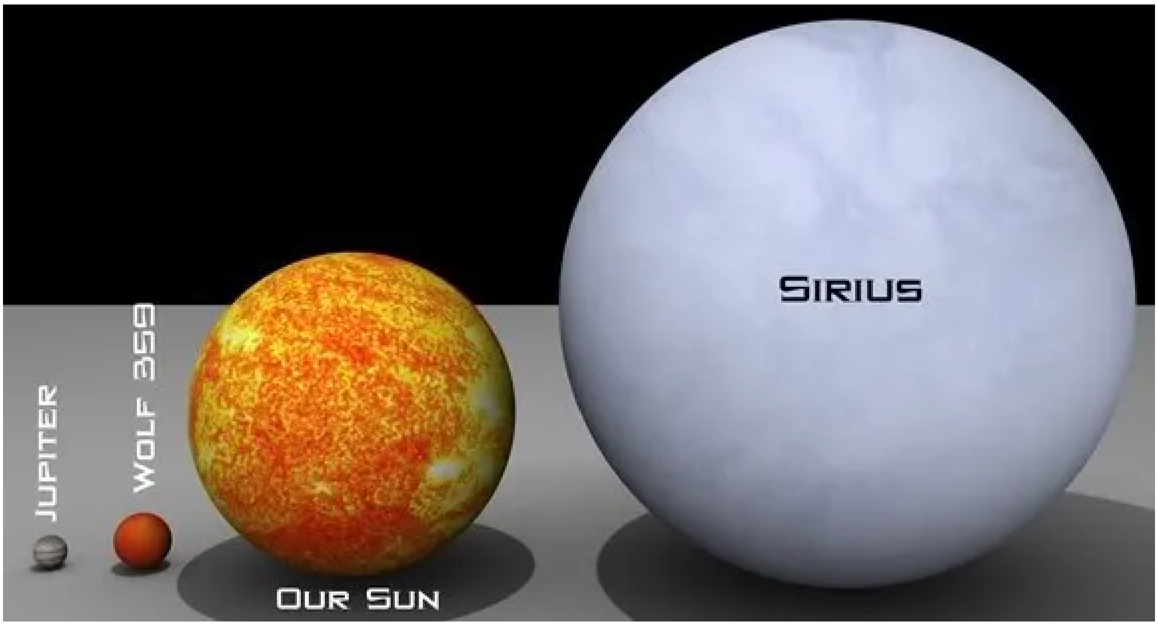


The gas giants are mostly hydrogen! Let's throw them into the Sun!

If the Sun is running out of fuel, then let's add more! We have four gas giants composed majorly of hydrogen in the outer solar system that aren't really doing anything useful; perhaps we can throw them into the Sun to get us a few extra years? Aside from the gargantuan amount of energy required to "throw" a planet into the Sun, it turns out that this idea is actually counterproductive in increasing its lifespan. Though throwing the gas giants into the Sun would give it more fuel to burn, the additional mass would increase the gravitational pressure inside the Sun, causing it to burn a little hotter than before. This new hotter equilibrium temperature would cause hydrogen to be burned at a proportionately faster rate, actually decreasing the Sun's lifespan. Throwing all of the gas giants into the Sun (only about 0.14% of its mass) would ultimately decrease its lifespan by about 30 million years. What's worse is that the more mass you try to put in, the shorter the Sun's lifespan becomes…

Okay… Less Fuel!

If adding mass decreases the lifespan of the Sun, then perhaps we can prolong its lifespan by doing the opposite: taking mass out! Red dwarf stars are the most abundant type of star in the cosmos, and are unique because of their astonishingly low masses and correspondingly long lifespans. The smallest red dwarf stars are estimated to have lifespans upwards of 5 trillion years; more than 350 times the current age of the universe! If we could find a way to suck all of the helium and most of the hydrogen out of our Sun so that it barely qualifies as a star, then perhaps we could prolong its lifespan equally as long. The lower limit for this procedure would leave our Sun at a meager 8% of its current mass, but would theoretically allow it to survive for trillions of years.



The Sun compared with stars of various sizes. Red dwarf stars like Wolf 359 may have lifespans of trillions of years.

There are, however, several problems with this solution. First of all, having a colder, smaller Sun would force us to relocate our home planet closer to ensure that it remain in the habitable zone. Provided we could find a way to do this, putting our planet this close to our new Sun would threaten tidal locking, a process by which one side of a planet always faces the host star. This phenomenon may leave one side of the Earth as a scorched wasteland, and the other as a barren tundra, which would be detrimental to life on Earth. Furthermore, small stars are incredibly magnetically active, shooting lethal solar eruptions on timescales that would extinguish any life which hasn't adapted to it. Unless we wanted to spend the time and energy to cope with all of these problems, shrinking the Sun to such a scale may not be a great idea.

Another option could be to siphon just enough mass from the Sun to place Venus within the habitable zone, and then move Earth's life there after terraforming it. This would avoid the tidal locking and deadly flare problems generated by creating a tiny red dwarf star, while perhaps prolonging the lifetime of our Sun significantly. To achieve this, we would have to extract about 17% of the mass of the Sun, leaving it just within the G-type star threshold. Even if this could be done, it would only extend the life of our Sun by about 600 million years; not bad, but probably still not worth it.

Replace the Sun's Helium with Hydrogen

So we can't add mass and we can't really take mass out. There may, however, be another option. The Sun is constantly fusing hydrogen into helium in its core, slowly burning through its hydrogen fuel source until one day, the Sun will be composed almost exclusively of helium. This is what will inevitably cause the Sun to bloat into a red giant later in its lifetime. So, what if we took it upon ourselves to split the Sun's helium back into hydrogen to allow it to live… indefinitely?

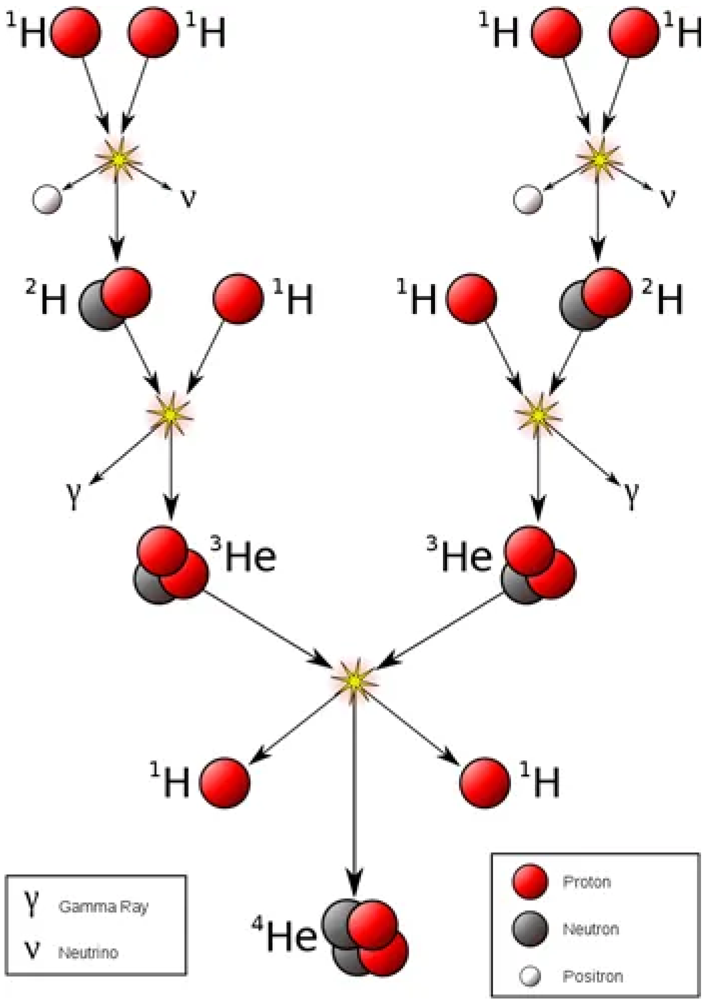


Diagram of proton-proton chain fusion, which dominates power generation in the Sun.

Fusion in the Sun's core is governed by the proton-proton chain, in which 6 hydrogen atoms (protons) undergo a series of steps to form a helium-4 atom, composed of 2 protons and 2 neutrons, and 2 more "new" protons. Without knowing the steps, it would appear that 2 protons are lost in the process, and that two neutrons spontaneously appeared in their stead. In reality, however, these neutrons were created when their parent protons lost what is known as a positron (for these intents and purposes, you can think of a positron as the piece of a proton that makes it positive). If we were to split the helium-4 atom back into its constituent particles, we would find that these neutrons don't appreciate being left unbound. Over the course of several minutes, the lonely neutrons will naturally decay *back* into protons and electrons. This process would leave us with the 6 protons we initially began with. If a way could be found to perform this process perpetually, it would allow the Sun to perform proton-proton fusion forever, allotting it an infinite lifespan.

The idea sounds logical in writing, but in reality there is one fatal flaw with it: energy. The energy engendered by the Sun from fusion of hydrogen into helium in its core is smaller than the energy it would take to split that same mass of helium back into hydrogen (kind of obvious when you think about it, otherwise the Sun would split helium-4 as soon as it was created). The binding energy of helium-4 is about 6% more than the energy produced by proton-proton fusion, which means that even if we were to capture all of the Sun's energy output with a 100% efficient Dyson Shell, and use all of that energy towards splitting the Sun's helium back into hydrogen, we would always be falling behind the Sun's helium production. Still, such a system would allow us to greatly extend the lifespan of our Sun, even if it isn't indefinite. Provided we can't procure another energy source to make up for that missing 6%, splitting the Sun's helium back into hydrogen would prolong the lifespan of our Sun to about a trillion years.

Artist's impression of a Dyson Shell under construction (Danielle Futselaar).

Conclusion

We may eventually have the capability to prolong the lifespan of our Sun, but would it be worth it? A billion years *is* a long time from a technological standpoint; we have no idea what kind of species we will be in such timescales (assuming we're still around). It may turn out that the benefits of such a procedure would not be worth the sheer amount of effort required to make it possible, and that interstellar travel is indeed more practical for the preservation of life on Earth. Then again, it may be considered wasteful not to try to prolong our Sun's life if the alternative was to simply hop from one solar system to the next each time our new host star was about to die. As with anything related to the future of our species, only time will tell.

As a race, we are upward bound. We vie to tackle the challenge of exploring the universe around us by any means necessary, hopefully taking that hunger for discovery with us to the stars. As we evolve off of our home planet and into the galaxy, we may find that we are more alone than we had once hoped. If this is true, extra care needs to be taken to preserve the miraculous instance of life in the cosmos that is planet Earth. However it is achieved, life on Earth must be provided the opportunity to outlive even the lifespans of the smallest, most steadily burning stars. Though our own Sun will eventually run out of fuel and die, let us hope that humanity's perseverance and desire for exploration of the unknown never does, no matter how we decide to pursue it.

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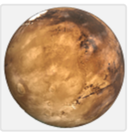

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Time is a dimension. Space is a frontier. We use one to study the other, and both to study ourselves.

Written by Brandon Weigel

I love astrophysics, engineering, and the future! I crunch all my own numbers, so if you have any questions please let me know! - brandonkweigel@gmail.com