Life and Fate

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In response to "The Good Soldier" (Vol. 5, No. 2).

To the editors:

In *Until the End of Time*, Brian Greene describes the unavoidable cosmic fate awaiting us given the laws of physics that govern nature. In his review, David Berlinski argues that our free will is not governed by unavoidable forecasts. Are we merely passengers on a train driven by the laws of nature toward a destination that we cannot avoid? Or is there some way we might seize the control car and shape our future at will, adding a surprising twist to the cosmic plot? The answer to the latter question is space travel. Once achieved, we can then demonstrate that this is not, as Berlinski put it, "an argument among billiard balls about which pocket they might join." Rather, our cosmic fate will be in our own hands. Allow me to explain.

The accelerated expansion of the universe pushes resources away from us at an ever-increasing speed. Once the universe ages by a factor of ten, all the stars outside our Local Group of galaxies will be receding faster than light. They will no longer be accessible to us. Is there something we can do to avoid this fate? Following the lesson from Aesop's fable "The Ants and the Grasshopper," it would be prudent to collect as much fuel as possible before it is too late, for the purpose of keeping warm in the frigid cosmic winter that awaits us.[1] In addition, for the same reason that animals feel empowered by congregating in large herds, it would also be advantageous to reside in the company of as many alien civilizations as possible with whom we could share technology.

After writing a few papers on the inevitable and gloomy cosmic isolation thought to lie ahead in our long-term future,[2] I received an optimistic email from Freeman Dyson in 2011.[3] He suggested contemplating a vast cosmic engineering project to concentrate matter from a large-scale region around us into a small enough volume, such that it will stay bound by its own gravity and not expand with the rest of the universe. The project would be undertaken in collaboration with any neighboring civilizations, if they exist and are minded to cooperate.

Fortunately, Mother Nature has been kind to us. She spontaneously gave birth to the same massive reservoir of fuel that we would have aspired to collect by artificial means. Primordial inhomogeneities from the early universe led to the gravitational collapse of regions as large as tens of millions of light-years, assembling all their matter into clusters of galaxies. Each of these clusters contain the equivalent of 1,000 Milky Way galaxies. An advanced civilization need not embark on giant construction projects of the type suggested by Dyson. It only needs to propel itself into the nearest galaxy cluster and take advantage of the available resources as fuel for its future prosperity.

Our nearest cluster is Virgo, whose center is about 50 million light-years away. Another massive cluster, Coma, is six times farther. Advanced civilizations might have already migrated to other clusters in recent cosmic history, as our own ancient civilizations once moved toward rivers or lakes. After settling in a new cluster, an advanced civilization could hop from one star to another, harvesting their energy output like a butterfly hovering over flowers in a hunt for their nectar.

An added benefit of naturally produced clusters is that they contain stars of all masses, much like a cosmic bag that collected everything from its environment. The most common stars are a tenth of the mass of the sun and burn their fuel at a much slower rate. They are expected to shine for 1,000 times longer and could keep a civilization warm for up to 10 trillion years into the future. The nearest examples of dwarf stars, Proxima Centauri and TRAPPIST-1, are known to host habitable, earth-sized planets around them. This implies that these abundant stars offer attractive parking spots for civilizations that rely on liquid water.

In order to traverse 100 million light-years within the age of the universe, a spacecraft needs to exceed one percent of the speed of light. This is 100 times faster than the speed of any chemical rocket our civilization has launched into space. The Starshot Initiative is the first funded project to develop a light-sail technology that could propel a spacecraft at a significant fraction of the speed of light.[4] If the project is successful, our civilization might one day

contemplate a journey to the Virgo or Coma clusters. This would be an impressive feat of long-term planning. When looking at billion-year-old photo albums, our descendants may reminisce about the era that their parent technological civilization spent within the Milky Way galaxy. By that time, our original home will be receding from them at an ever-increasing speed until its image freezes and fades away for eternity.[5]

Would this accomplishment demonstrate that humans have free will? Or are we merely following what nature destined us to do, without even knowing it? So long as Brian Greene finds this end surprising and beyond the scope of his book, I rest my case.

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1. "The Ants and the Grasshopper," *Aesop for Children* (Library of Congress, n.d.).
2. Abraham Loeb, "Long-Term Future of Extragalactic Astronomy," *Physical Review D* 65, no. 4 (2002): 047301, doi:10.1103/PhysRevD.65.047301. Kentaro Nagamine and Abraham Loeb, "Future Evolution of Nearby Large Scale Structures in a Universe Dominated by a Cosmological Constant," *New Astronomy* 8, no. 5 (2003): 439, doi:10.1016/S1384-1076(02)00234-8. Kentaro Nagamine and Abraham Loeb, "Future Evolution of the Intergalactic Medium in a Universe Dominated by a Cosmological Constant," *New Astronomy* 9, no. 8 (2004): 573, doi:10.1016/j.newast.2004.03.003. Abraham Loeb, "Cosmology with Hypervelocity Stars," *Journal of Cosmology and Astroparticle Physics* 4, no. 23 (2011), doi:10.1088/1475-7516/2011/04/023.
3. Nathan Sanders, "Avi Loeb and Freeman Dyson on the Future of the Universe," *astrobites*, February 3, 2011.
4. Breakthrough Starshot Initiative.
5. Loeb, "Long-Term Future of Extragalactic Astronomy."

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