Surfing on a Flash of Light from an Exploding Star

By Abraham Loeb on December 26, 2019

A common sight on the beaches of Hawaii is a crowd of surfers taking advantage of a powerful ocean wave to reach a high speed. Could extraterrestrial civilizations have similar aspirations for sailing on a powerful flash of light from an exploding star?

A light sail weighing less than half a gram per square meter can reach the speed of light even if it is separated from the exploding star by a hundred times the distance of the Earth from the Sun. This results from the typical luminosity of a supernova, which is equivalent to a billion suns shining for a month. The Sun itself is barely capable of accelerating an optimally designed sail to just a thousandth of the speed of light, even if the sail starts its journey as close as ten times the Solar radius – the closest approach of the *Parker Solar Probe*. The terminal speed scales as the square root of the ratio between the star's luminosity over the initial distance, and can reach a tenth of the speed of light for the most luminous stars.

Powerful lasers can also push light sails much better than the Sun. The *Breakthrough Starshot* project aims to reach several tenths of the speed of light by pushing a lightweight sail for a few minutes with a laser beam that is ten million times brighter than sunlight on Earth (with ten gigawatt per square meter). Achieving this goal requires a major investment in building the infrastructure needed to produce and collimate the light beam.

Alternatively, a civilization that happens to reside near a massive star, like *Betelgeuse* or *Eta Carinae*, could park numerous light sails around it, cleverly awaiting the powerful explosion that would launch these sails to the speed of light at a minimal cost.

Of course, there are challenges. First among them requires patience. Massive stars live for millions of years and it is difficult to forecast the exact timing of their explosion because of uncertain factors, such as the mass loss during their evolution. For example, *Eta Carinae* has a lifetime of a few million years, but forecasting its death to a precision of millennia would be as challenging as predicting in which year an old person might die after approaching the average life expectancy.

The sails can be transported to their destination well in advance of the explosion using cheap chemical rockets. The journey would take millions of years across the molecular cloud that gave birth to the massive star. Only civilizations in the vicinity of that cloud could use chemical propulsion to reach the star before it explodes. The same rocket engines would enable the sails to hover in the appropriate orientation relative to the star, given the desired direction for their journey after the explosion.

But as the Jewish saying goes: "there are many reasons for concern". First, as in *Starshot*, the sails must be highly reflective so as not to absorb too much heat and burn up. Second, once the sails are placed in orbit around the massive star, they will be pushed away by the bright starlight or mass loss prior to the explosion. To avoid this danger, one could deploy the sails in a folded configuration and equip them with a switch that would open them up like umbrellas as soon as the explosion flash begins to rise. Third, even though the launch can start from a distance that is a hundred times larger than the size of the exploding star, care must be taken in selecting particularly empty acceleration paths - clear of any stellar debris. With a relative speed approaching the speed of light, dust particles would puncture the sail like miniature atomic explosions and gas particles will slow down the sail as soon as it sweeps ambient matter with a weight comparable to its own. Once the sail reaches its terminal speed, it could fold into a needle-like configuration with a small cross-sectional area along its direction of motion to minimize damage and friction.

Very massive stars, like *Eta Carinae*, might collapse to a black hole and produce powerful beams of radiation that astronomers observe across the Universe as gamma-ray bursts. Sails that happen to lie in the direction of these beams at the time of the explosion, would get an extraordinary boost that could bring to a relativistic Lorentz factor of a thousand, enabling them to cross the entire Milky Way galaxy in less than a human lifetime - as measured in their rest frame. Electric sails could also approach similar speeds while surfing on the relativistic winds produced by pulsars or black hole jets.

The bright flash of light from the explosion of a star might be preceded by intense bursts of neutrinos (as detected from *SN 1987A*) and gravitational waves, but it would be difficult to tap the push from these components since they interact very weakly with matter.

In view of their potential utility for propulsion, massive stars or their supernova remnants should serve as interesting new targets in the *Search for Extraterrestrial Intelligence (SETI)*. The light sails surrounding them might be too small to find individually, but the sum of their bow shocks or communication signals could be detectable with existing telescopes.

Is there any evidence for fast moving material in supernova remnants? Yes, there is, but it likely originates from natural causes. Supernova ejecta typically move out at a tenth of the speed of light, and faster moving material was detected in remnants such as Vela and W44. In addition, the most powerful explosions, such as hypernova or gamma-ray bursts, are known to produce natural outflows approaching the speed of light, and isolating artificial components within them would be challenging.

Sailing on natural flashes to the speed of light saves on the expensive construction costs of artificial launch systems. This conceptual paradigm echoes the spirit of *Dyson spheres*, the megastructures hypothesized by Freeman Dyson for harvesting the energy (instead of the momentum) output of stars. If we are lucky to have many technological civilizations in our Galaxy, there might be swarms of light sails around massive stars, patiently awaiting their explosions. But before we let travel agencies market these fireworks as attractive tourist destinations, it would be good to know the answer to one question: are the environments of massive stars already as crowded with surfers as the beaches of Hawaii?

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(Credit: Nick Higgins)