The Stars are In Our Reach

By William Mook

The announcement that a new, very earth-like planet has been found[1] is quite exciting. It prompts me to share some big ideas that require several textbooks to support fully. However, in this article I can only give a brief outline to support the larger vision;

It is time to understand that:

1. squeezed photons can be made to interact so as to produce positrons and electrons efficiently;
2. positrons and electrons form a Bose-Einstein condensate, a superfluid, that is a new molecule, positronium;
3. positronium (Ps) may be stored indefinitely in appropriately structured crystals and manipulated with appropriate nano-scale structures;
4. the superfluid density can exceed that of iron (8 kg/l);
5. the open-lattice crystalline structure to control Ps approaches that of aerogel (800 µg/l);
6. spintronics is an extension of electronics that manipulates electron spin in addition to bulk properties of current;
7. controlled re-combination of Ps elements via 'polarized' Ps pairs creates a controlled beam of polarized gamma rays via conservation of momentum;
8. inverting the photon-squeezing process expands gamma rays to longer wavelengths where they may be further processed.

While these steps are done at present only on the laboratory scale, and not very efficiently in some cases, the physics is clear and also the result: we can make anti-matter powered photon rockets.

We are at the same stage as Goddard was when he did his calculation that showed you could put a ton of flash powder on the moon and observe it with a telescope on Earth.

Figure 1: Goddard in 1916, 1926, and 1940.

[1] www.skyandtelescope.com/astronomy-news/exoplanets/earth-like-planet-found-yet/.

Goddard was inspired by Constantin Tsiolkovsky's rocket equation, first published in English in 1909, and worked ceaselessly at building rockets the rest of his life.

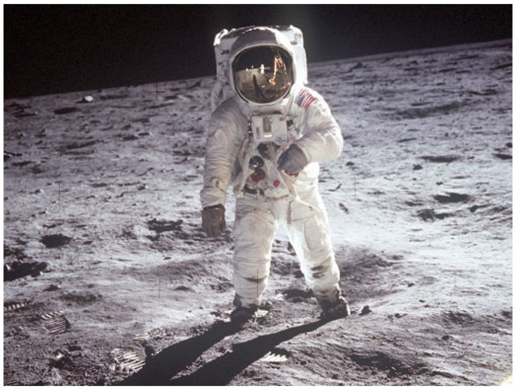

Figure 2: Neil Armstrong on the Moon, 1969.

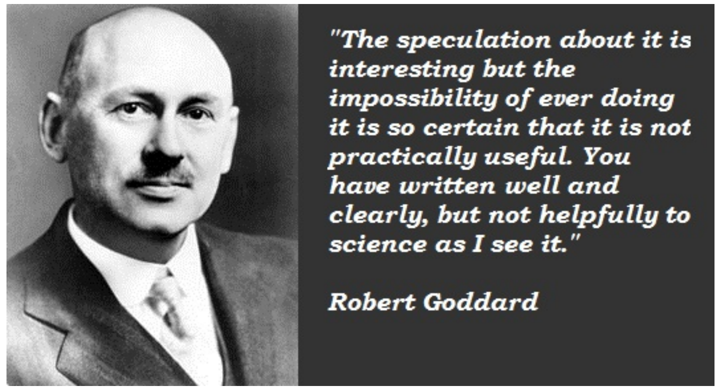

Figure 3: *Popular Astronomy'*s response in 1907 to Goddard's paper on the possibility of navigating interplanetary space.

Sixty years after Tsiolkovsky published his equation in English, 53 years after Goddard conceived of sending a rocket to the moon, humanity sends payloads to the moon.

Now, Rindler has re-worked the rocket equation for relativistic flight.

Tsiolkovsky's original equation is

$$V_f/V_e = LN(m_0/m_1)$$

where V_f = final velocity, V_e = exhaust velocity, m_0 = initial mass, m_1 = final mass.

Rindler's equation for relativistic rockets (propelled by Ps-driven photon rockets) is

$$V_f/c = Tanh(LN(m_0/m_1))$$

Where V_f = final velocity, c = speed of light, m_0 = initial mass, m_1 = final mass.

With a 10,000 to 1 mass ratio possible with the aerogel-containing Ps system, we have

$$V_f/c = Tanh(LN(10{,}000)) = 0.99999998 = 99.999998\% \text{ light speed.}$$

A two-impulse system has the square root of this mass ratio to carry out the two impulses so, can travel and stop where we're going.

$$V_f/c = Tanh(LN(100)) = 0.99980002 = 99.98\% \text{ light speed.}$$

A four-impulse system takes the fourth root of the original mass ratio, so can travel out and back again.

$$V_f/c = \text{Tanh}(\text{LN}(10)) = 0.98019202 = 98\% \text{ light speed.}$$

Star Ship

Consider a bullet tank with spherical end caps that is 2,653 meters long and 640 meters in diameter. It has a cylindrical area that is 2,012.5 m x 2,012.5 m totaling 4.05 million sq. m., or 1,000 acres in area. Studies by Gerard K. O'Neill, NASA, and Stanford University in the 1970s and early 1980s before O'Neill's death indicated that this pressure vessel is on the small side of what is possible. The total mass of a vessel that is spun at a rate of once every 36 seconds to reproduce Earth-normal acceleration inside is 7.5 metric tons per square meter of surface area when equipped for long-term human habitation. A total of 40 million tonnes – including end caps.

A spherical tank of crystalline material holding 8 tonnes of Ps per cubic meter and massing 800 μg per cubic meter is now considered.

The tank has a volume of 137.25 million cubic meters. It therefore holds 1.098 billion metric tons of positronium and masses less than 110,000 metric tons. Combined with the habitat just described, the system has a mass ratio of 28.45 to 1.

Not only can a massive solar pumped laser be built to create the immense amounts of Ps needed for this trip in reasonable amounts of time, but that laser will also be capable of generating a beam to accelerate the ship without using any of its stored positronium.

The same 640 m diameter emitter that operates at the tail end of the star ship to propel it using Ps can also be made to reflect energy beamed to the ship to produce a propulsive effect as well. Dr. Young Bae, formerly with US AFRL and currently founder and President of Bae Aerospace, has demonstrated a unique method of using conjugate optics to recycle photons efficiently. This makes what he calls a photonic thruster that permits efficient propulsion at low speeds while more traditional laser light sails proposed by Robert Forward are used at higher speeds. At extreme relativistic speeds, Ps is used.

In this instance, the laser energy accelerates the ship at 0.2 g until it reaches 0.5 c in 30 months. It then uses stored Ps to continue to accelerate until 98% light speed is attained. This takes another 30 months ship time. At speed, every 10 weeks aboard ship is 1 year star time. Spending 50 years aboard ship permits travel to a distance of 250 light years. Five years prior to arriving at one's destination the ship slows at 0.2 g to arrive at its destination.

Within 250 light years of Earth there are 3.5 million stars. Of these 263,257 are G-type stars like the sun. By 2020, the Gaia Spacecraft will have mapped over 1 billion stars – all stars out to a distance of 1,645 light years. About 75 million of these stars will be G-type stars, like the sun.

Aboard the habitation vessel, a 98% outward g-force produced by rotation, combined with a 20% longitudinal g-force produced during acceleration yields 100.0% g-force tilted at an angle of 11.53 degrees from vertical during boost. During cruise with no boost or on orbit with no boost, the outward g-force normal to the cylindrical surface is maintained at 98% Earth normal.

The same technology that makes photonic drives and very powerful lasers possible by stretching gamma rays produced by controlled Ps decay is also used to mimic the spectrum of the sun on the interior of the ship. At peak sunlight on Earth 1,000 W/m^2 is present. So too on the interior surface light is produced to mimic Earth conditions at noon on a sunny day. This requires a 4 GW light bulb. This bulb is large by conventional standards, small by the standards of the drive system. A diurnal 24-hour cycle leaves us with 250 W/m^2 average output – or 1 GW continuous load, requiring 86.4 trillion joules per day to be maintained. This requires less than 1 gram of Ps per day and totals 350 kg per century.

So, only 1 tonne of Ps of the over 1 billion tonnes described is sufficient for most non-propulsive needs for centuries.

Interplanetary navigation – even at high-speed constant-g boost – requires less than 0.3% of the stored Ps over the same period.

Dr. Mark Roth has demonstrated suspended animation and this may be considered a solved problem for our purposes. Its use aboard the star ship described here allows rotation of crews and passengers, so that they may spend only a few months or years aboard ship in a conscious state, whilst engaged in a trip lasting decades or centuries.

Figure 4: Mark Roth.

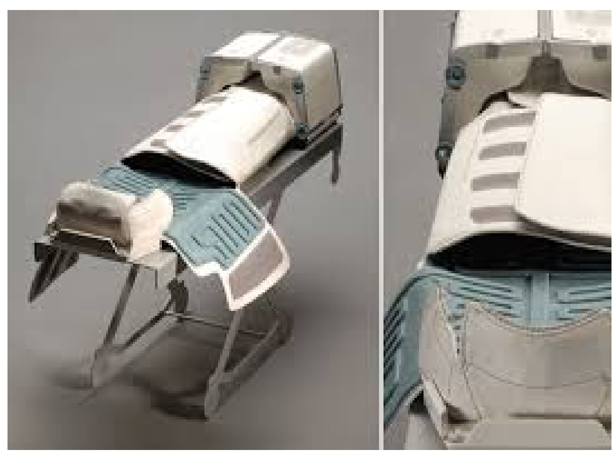

Figure 5: Suspended animation capsules.

This seems like a fantastic vision of the future. Perhaps it is out of place in a world that is short of energy and resources; a world that converts less than 4 tonnes per year of matter to energy through a wide range of chemical processes. A billion tons of Ps, even produced with perfect efficiency, would take 250 million years of our current energy output to produce, even if we did nothing else.

Figure 6: Suspended animation.

Of course, all this says is that we will not be using current techniques to produce the Ps for this trip.

Star Ship Supply Chain

And that is the point. A U.S. President once said of the moon program, “We go to the moon and do the other things, not because they are easy, but because they are hard.”[2] By doing these hard things, we develop skills that turn hard problems into easy work with the solutions we create.

IBM has recently, in 2013, completed the IBM Jeopardy Challenge, proving that computers can now pass the Turing Test. Vik Olliver and Adrian Bowyer built the world’s first self-replicating machine system in 2005.

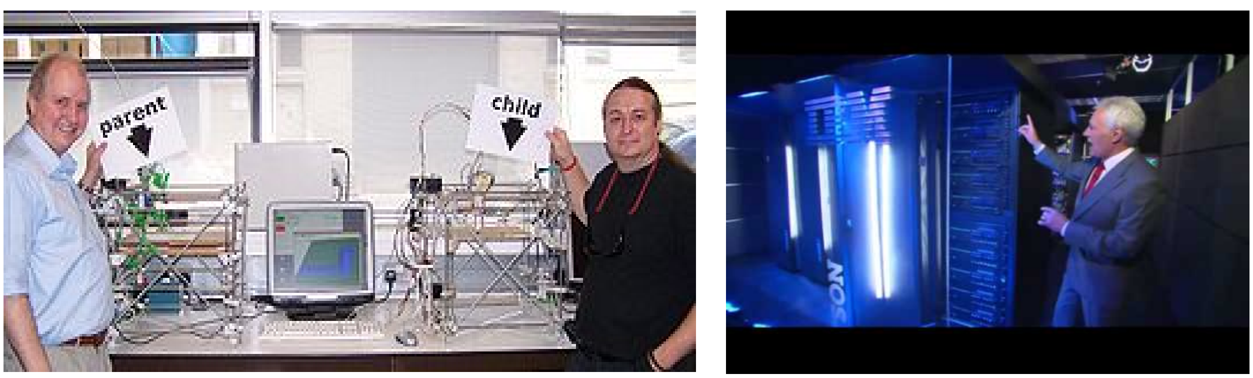

Figure 7: The first self-replicating machine system.

We can use an artificially intelligent self-replicating machine system that operates on the surface of the sun to build and fuel our star ships. These machines will extract metals from the solar atmosphere to replicate. They will use abundant solar energy to fill crystals made on the sun with Ps.

[2] John F. Kennedy, “Address at Rice University on the Nation’s Space Effort,” September 12, 1962.

Practical Steps and Processes

Solar Panels on the Solar Surface

Let us consider a 1-square-meter solar collector of this type, deposited on the sun. First, would it even be possible for something to survive in material form on the sun? Well consider a sheet of glass like material that is 91% transparent. Exposed to 63.6 MW, each square meter would absorb 5.73 MW and rise to a temperature where it would radiate that energy from two square meters (front and back). Stephan Boltzmann tells us what this temperature is: 2,665 K. Well within the capacity of many materials to withstand. Similarly, if we create a nearly perfectly efficient solar collector that converts the incident energy into Ps and stores it, it need not get too hot. In a similar way, if the sun's hydrogen and helium are reflected efficiently from the surface, whilst the heavier species of elements are admitted and then cooled, these too can be dealt with.

Since the technology that makes laser propulsion and photon rockets possible for star travel involves the same processes and the same energies or higher, construction of this type of solar panel is the path toward star travel.

Analysis of the photosphere and above, the energy and materials available at the solar surface, permits a square meter of Ps-storing solar panel to self-replicate every nine seconds. Since the solar surface totals 6.08 square exameters (6.08×10^{18} m^2), a single square meter grows to cover the entire solar surface in

$$t = t_0 * LN(6.08 \times 10^{18})/LN(2) = 9 * 62.4 = 561.6 \text{ seconds}$$

Of course, moving from the point of impact to the opposite side of the solar disk in this time requires moving at 7,781 km/sec on average. In actual practice, and digital modelling shows this, speeds approach five times that. This requires substantial amounts of energy to achieve. An optimized model would likely take something on the order of 10 hours to complete this task.

So, 10 hours after the arrival of the first well-engineered solar surface panel, the sun turns off! That seems like a side effect we must consider more carefully to avoid.

Controlled Star

One solution would be that such a collector, equipped with an autostereoscopic display on the backside, made of the same array of photonic elements that made photon rockets possible, would also be capable of converting the entire solar disk into a large photonic emitter: a single optical element with a radius of 695,500 km – emitting wavelengths as short as 200 nm efficiently. The Rayleigh criterion for such an optical element says a 200 nm laser beam emitted from it would diverge at a rate of 3.32 meters per light year of range! An Airy disk of 640 m diameter could be formed at a distance of 197.2 light years!

An array of emitters on the surface of the sun, operating on the back side of the solar panel array just described, would also reproduce conditions on worlds around the solar system and even nearby stars, so that the sun would still be visible and appear to be operating as always, even though 99.9999% of the energy the sun now wastes into space, is captured and converted to positronium molecules stable in a crystalline lattice. Further, the sun is surrounded by nanomachinery that extracts and converts the metals in its atmosphere to usable forms of machinery, in addition to the Ps energy source.

Since self-replicating machinery is a problem solved back in 2005, we can see that all that must be done to make these sorts of vision a reality is to perfect the steps needed to create a square centimeter of a self-replicating positronium-storing, solar collector capable of operating on the solar surface. Such a collector would be capable of operating in a variety of modes that make construction of the spacecraft and its propulsion system, including fuel supply, possible.

The sun, properly equipped, produces 4.3 million metric tons of Ps per second along with many millions of tons of other material, which can be fabricated into anything we describe to the network of panels. Furthermore, the energy in part runs a vast computing and information network that can be tapped to solve problems.

Diaspora
The rate of Ps production allows one ship of the type just described to be sent from Sol every 255 seconds: a total of 123,500 ships per year. Of course, using the laser beam trick to accelerate each to 0.5 light speed and supplying our local needs for energy and materiel reduces this number by about half to 5,000 ships per month, since supporting acceleration of ships with laser beams reduces Ps production and since Ps use on Earth and within the solar system reduces the amount available for use on star ships.

At 2,500 persons per ship, this is 150 million persons leaving the solar system per year. This is 2.1% of the world's 7.12 billion people. This reduces population on Earth despite unconstrained population growth. Due to time dilation and suspended animation, replication in transit does not occur efficiently. If we started in 2015 with this program, by 2057 – the 100th anniversary of Sputnik – we would have only 3.2 billion people on Earth, the same number that were on Earth in 1957 when the space age started with the launching of Sputnik.

The 263,257 G-type stars within 250 light years of Earth will be filled at a rate of 60,000 star ships per year. Licensing travel to the most distant G-type stars in this sphere first, and rolling back 1 light year per year, creates an interesting situation; namely, one where everyone arrives at their destination at precisely the same time! This means all the star colonies will start out at exactly the same time with the same population. The only difference is that later departures will have the advantage of higher technologies developed in the interval between the more distant departures and the one closest in. This creates a sort of natural dispersion of skills and capabilities.

The average number of people per star is 48,000 to 60,000, arriving in 20 to 25 star ships of the type described above over a 65-year period. This will take only 65 years, because at our current population level, we will run out of people to send. Starting today with 7.12 billion of us and dispatching 150 million explorers per year to G-type stars within 250 light years in this way reduces the number of people on Earth to 221.6 million by 2080 AD. So, sometime between 2057 AD, with 3.2 billion on Earth, and 2080 AD, with 221.6 million on Earth, we expect the demand for star travel to subside. With that, licensing would be liberalized, allowing free access to all and to any star system thereafter up to population growth numbers, of about 1.14% – or with 221.6 million on Earth, 2.52 million per year. Using the type of star ship just described, population per ship drops from 2,500 to 42, which changes payload and production rate hardly at all. After 2080, there will be nearly 7 billion of us, in this scenario, in hibernation, in transit to the stars, for another 195 years. After that, we will encase a quarter million more G2-type stars and begin building large artificial worlds with the material and energy made available with the technology we create today.

With similar advances in ageing research,[3] many of us will be alive then to see it.

If we act now.

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About William Mook, PE: Bill Mook has innovative science and technology ideas for more subjects than anyone you have met. Those subjects range from the rocket history to sustained industrial futures in Space. He approaches his subjects from a mix of engineering knowledge through financial analysis and imbeds them in philosophical rationale as a foundation to support his statement *"The heavens will open to humanity."* He has had management and fiscal responsibility on Fortune 500 R&D teams and provided analytic work for the White House during both the Clinton and Bush Administrations. He holds patents for ground-breaking product developments. He is a member of the Board of Editors for the *Journal of Space Philosophy*.

Editors' Notes: From his office in New Zealand, Bill Mook propels readers farther and faster through Space with science and technology theory than they have ever been before. Bill's imagination for projecting humans in the heavens is a valuable addition to the Global Space Community. See, also, his previous article in the Fall 2013 issue of the *Journal of Space Philosophy*. ***Bob Krone and Gordon Arthur***.

[3] www.ted.com/talks/aubrey_de_grey_says_we_can_avoid_aging.