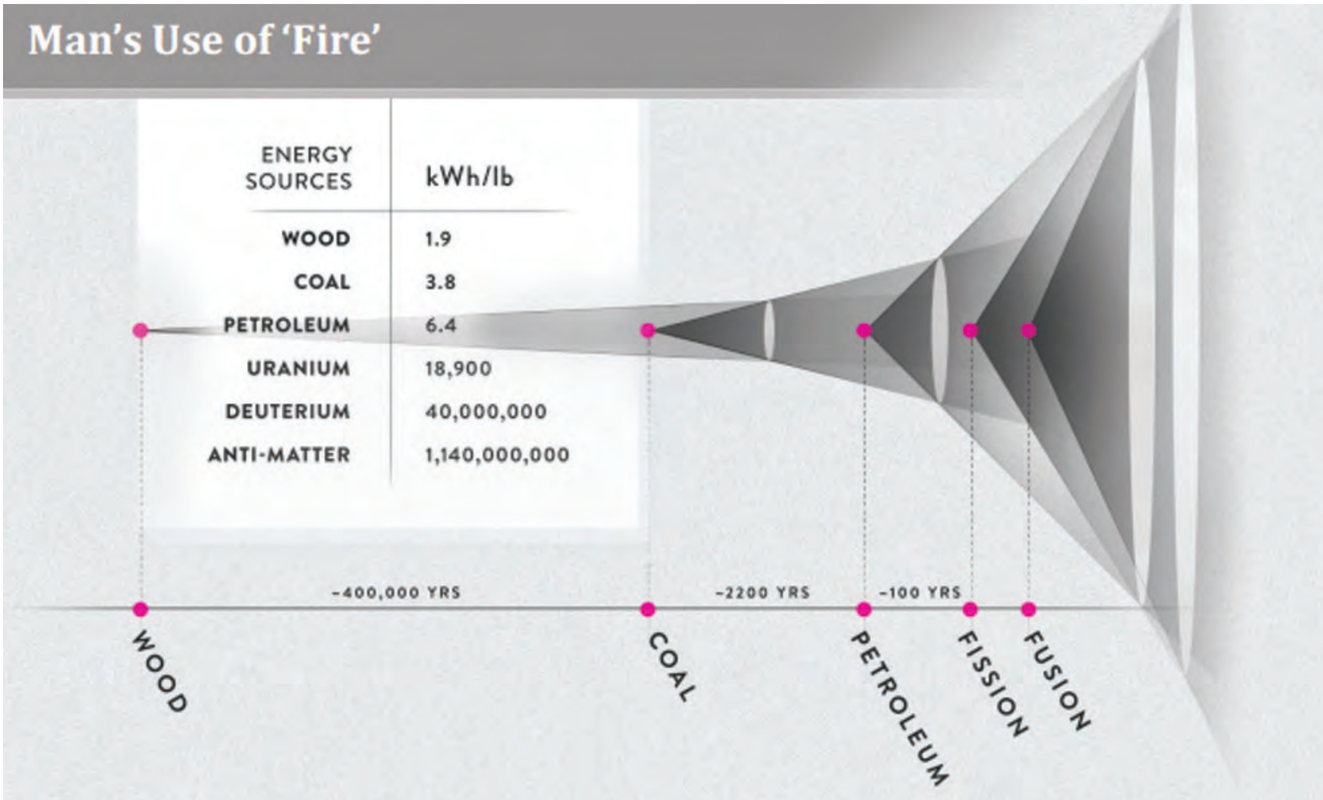

The Space-Time of Increased Energy Flux Density

by Creighton Jones

In contemplating the ability of mankind to increase his reach into the universe, we confront a curious irony respecting the essence of physical space-time itself. In general, we find that the power to further expand our reach into more distant nooks of the universe is a function of gaining an expanded mastery of increasingly "smaller" dimensions of physical space-time, a process which will come to be measured in terms of an increase in energy flux density (EFD). In other words, our ability to harness the increased power of physical reactions at increasingly smaller scales has correspondingly resulted in our gaining a power to go increasingly further out into our surrounding world, to the point that our closest binary star neighbor, Alpha Centauri, is now potentially within reach. This process has the character of adding, through creative discovery, a new dimension to the manifold of discovered principles of our universe. For example, the increase in power achieved as we shift our understanding of chemistry beyond the molecular level to the atomic level, (as with the shift from combustion of fossil fuels to controlled nuclear reactions) has opened up new potentials for physical control of processes, beyond what was possible in the domain of the lower energy density platform.

Coupled to this ironic relationship of the very large and the very small, is the challenge that this investigation poses to our assumptions about the nature of space itself: that space is a universal manifestation of extension itself, as deduced from a naïve, largely vision-based concept of space. The fallacy in this notion of spatial extension becomes clearer as we are forced to confront very real physical boundary conditions in space flight, especially when the prospect of human travel is involved, where very real challenges arise which might not be so obvious when such great "distances" are only considered in the abstract. That is, although in the domain of fantasy we can envision infinite linear extension into the increasingly small or the increasingly large, when this is at-

Figure 1
Exhaust Velocities for Different Rocket Fuels

Chemical	3,000 meters/sec
Fission	50,000 meters/sec
Fusion	100,000,000 meters/sec

EIR

One of the major factors that determines how fast the spacecraft can go is the speed at which the propellant comes out as exhaust. Chemical rockets, like today's Space Shuttle, burn liquid hydrogen and liquid oxygen, and the vapor that comes out as the exhaust is traveling at 3,000 meters per second. Nuclear fission provides much faster-moving exhaust particles—50,000 meters per second—but the promise of fusion is that it will provide orders of magnitude increases in exhaust velocity—to 100 million meters per second.

Figure 2
Specific impulse for different Rocket Fuels

Chemical	450 seconds
Fission	1,000 seconds
Fusion	100,000 seconds

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Another way of comparing different propulsion fuels is by measuring their specific impulse. This figure, measured in units of seconds, describes the efficiency of the fuel used—it is the impulse per unit weight of the rocket propellant. Here, again, fusion promises orders of magnitude improvements over both chemical and nuclear fission fuels.

tempted in physical practice, we continually run into successive limits that can only be overcome through the introduction into practice of a newly discovered principle. This will become clearer as we proceed.

Onward to the Stars

A leading consideration when proposing a mission into the cosmos is the sheer weight of the spaceship with all its necessary instrumentation, because the heavier the payload, the more costly it is to launch, as measured in physical terms. The heavier the payload, the more thrust you will need to get it out of Earth's, or any other body's, gravitational well. Moreover, each fuel source employed defines certain upper limits in terms of mass, distance, and time relations achievable for a mission. Thrust, which is a measure of the force that accelerates the rocket, is a function of the fuel type you are burning: how much and at what rate. So generally, the larger the payload, the greater the amount of fuel required. It must be kept in mind that the fuel yet to be burned has to be calculated into the equation for weight. So, for example, longer trips will naturally require carrying more fuel, and that fuel has to be taken into the weight consideration of the ship, up to the point in the journey that the fuel is used for propulsion.

This already confronts us with the physical reality that the choice of use of any of the various fuel sources must be considered from the standpoint of the physical limits of its usefulness, as understood by such measures as the relative distance, and the time to traverse that distance, that the fuel can be employed for, as this is a function of what can be characterized as the Energy Flux Density (EFD) of the particular fuel source. EFD is a measure of the power brought to bear per unit of physical space-time; the more action or energy that you can concentrate in a given volume, the higher the energy flux density you achieve. This is a qualitative, as opposed to simply a quantitative phenomenon, and the question of the achievable density is the key. For example, although you could produce, through the combustion of around 20 billion molecules of methane (the primary component of natural gas), the 200 MeV of energy produced through the fission of a single atom of U-235, the diffuseness (volume) and quality (form) of the energy generated in natural gas burning renders it incapable of triggering a nuclear chain reaction. Compare that to the case with an initial fission event which releases some of its energy in the form of high-velocity neutrons, operating at an atomic scale, that then go on to trigger subsequent fission events. Not to mention the fact that through the chain reaction, new elements are produced through the transmutation process. Hydrocarbon combustion simply doesn't have the concentration of energy or power, or the *quality* of action, that is, the EFD, to effect processes at an atomic scale. So fuels with a higher EFD, as compared to those with a lower EFD, can produce the same relative amount of energy, but with less fuel and in a form which is of a qualitatively higher power.

A Brief Overview

This qualitative distinction between different fuel types, as measured in terms of EFD, pertains to modes of travel and dominion of human control. The first non-muscle driven form of transportation, was sailing. Wind power, as well as ocean currents, both of which are used to drive ships across seas and oceans, are a function of disproportionate solar-thermal heating of the atmosphere and hydrosphere and represent a relatively low EFD, that leaves mankind at the whim of relatively uncontrollable external factors. The next level in increased power to travel, comes in the form of liberating, through combustion, the stored energy of organic compounds in wood, and more importantly coal. Coal-driven locomotion afforded mankind the ability to have self-determined control of the continents. Man was able to advance further with the development of petroleum-based fuels, which utilized a greater depth of understanding and refinement of processes at the molecular level, where the higher energy-to-weight ratio allowed for their use in flight, adding yet another dimension to man's domain. The upper limit we have reached in the use of chemical reactions for propulsion is that used in rockets, such as the Saturn V rocket, used to put a man on the Moon.

The next level of development is that of controlling processes at an atomic level, that is, nuclear reactions. With an energy density orders of magnitude above that of chemical fuels, nuclear power provides an ideal power source for a reusable craft to fly heavy-load missions, allowing for manned control of the space between low Earth orbit and the Moon, as this was envisioned in NASA's development of the Nuclear Engine for Rocket Vehicle Application (NERVA) program. Nuclear rockets could also be utilized for long-duration unmanned cargo transport, to such further reaches as Mars.

Beyond nuclear fission, lies the promise of fusion-powered rocket ships, to be realized through gaining a greater understanding and control of processes at the atomic and sub-atomic level. With the power density achieved with fusion power, we will have the ability to generate an acceleration of 1 Earth gravity (1-g), that would allow for ideal travel time and lift capacity to put humans on Mars and open up the entire Solar System, out to the moons of Jupiter, to manned exploration, and in the process, achieve velocities which are within an order of magnitude of the speed of light. The next achievement, which would bring us up against the current limits of understanding the processes in the universe, would be the controlled use of matter-antimatter reactions, and will require us to penetrate even further into the sub-atomic domain.

Here the challenge would not lie in producing the reaction, as it is with fusion, but in fact creating the material to be used in the reaction, i.e. the anti-matter itself. For this, we will need to expand, fundamentally, our understanding of what matter is, which necessitates making breakthroughs in our conception of sub-atomic properties, such as spin and charge. The proposed designs for the rockets themselves call for taking advantage of such anomalous quantum properties as super-position and quantum coherence, which will allow for achieving even greater material densities, a fundamental parameter for long-distance spaceflight. One such design was presented at the 2004 NASA/JPL Workshop on Physics for Planetary Exploration, where a team proposed using anti-hydrogen fuel in a Bose-Einstein Condensate state, which would allow for an even denser packing of material per volume than is otherwise achievable under standard material conditions. With matter-antimatter reactions, we are utilizing, in a near-perfect way, the conversion of matter to energy described in the famous $E= mc^2$ equation of Einstein. With the density of power this affords, rockets will be able to approach velocities over half the speed of light, which puts the nearest star to our Sun within reach, at a travel time of about 9 years. Again, the increased EFD and the new power this affords man – in this case, the expansion of the domain under man's control – is a function of adding new principles to our manifold through creative discovery.

A Biological Consideration

Considerations of achievable energy flux densities for different fuel sources take on even greater significance when you add "manned missions" to your manifold of parameters. At that point, you must account for biological and psychological effects of space travel, where the duration of the flight is of critical importance. First to be considered are the yet little-understood effects on the human body of prolonged exposure to various forms of cosmic radiation which we will encounter outside the protection of Earth's atmosphere. On-board shielding, to the degree that it develops, will provide some protection, but the greatest mitigation of effect will come through reducing the time of exposure by shortening the travel time. At present, the ideal duration of travel for a trip from the Earth-Moon orbit to Mars, for example, is that achieved by a ship operating at one gravity acceleration, which should offset at least the loading effects of microgravity exposure, and would put us on Mars in 7-10 days. As mentioned above, the one, and perhaps the only physically viable means of achieving this is through the use of directed fusion powered rockets. Also, a 7-10 day trip will be much more psychologically tolerable than the trip of many months we can expect from chemical rocket propulsion.

Conclusion

In conclusion, we must see that the ontological nature of reality is not one that can be understood from a naïve sense-derived notion of space and time. Rather, our active knowledge of physical space-time is constantly changing in a non-linear, qualitative fashion, as a function of the creative discovery of universal principles. Furthermore, our notions of scale, into the very large and very small, are intrinsically bound by those underlying principles, and our accessibility to processes at different scales is not a function of simple extension "out" or "in" so to speak, but of revolutions in our knowledge of the underlying order of the physical universe. This is demonstratively seen in mankind's leaps from lower to higher order Energy Flux Density platforms, and the power to act these leaps afford us at qualitatively different scales.