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Light of the Stars by Adam Frank (read July 2018)

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Over the past several years I have been thinking about climate change and sustainability in conjunction with the financial work that I do. You can't have long-term sustainability unless you address the growing carbon dioxide levels in the atmosphere and ocean. A review of this book said it spoke of simulations leading to sustainable and die-off scenarios. It potentially tied in well to a low growth scenario research paper I am involved with, so I dove in. The author tells an interesting story.

When investing, Charlie Munger (vice-chair of Berkshire Hathaway and sidekick of Warren Buffett) talks of the importance of inverting. In this case, we are interested in how long a human civilization might last, and so arguments are developed around how many other civilizations might have existed. Of course, the Earth (as long as we don't blow it up) will survive with or without us. It is a co-evolving biosphere, reacting to whatever is thrown its way (a great book about this is Alan Weisman's *The World Without Us*). It does not need humans. Humans are the experiment. The hope is that we will get past the current bottleneck, much like reaching Mach 2, and reach smooth sailing again.

Enrico Fermi's Paradox, "But where are they?" puts the search for extra-terrestrial intelligence (SETI) in perspective. Frank Drake developed seven factors that would need to be solved (each is a subset of the prior filter).

- Birth rate of stars
- Fraction of stars with planets
- Planets in the "goldilocks zone" that sustains life
- Percentage of planets where life forms
- Percentage of planets where intelligence evolves
- Percentage of planets with a technological civilization
- Average lifetime of a technological civilization

It is thought that a technological civilization could only appear after a planet had been in the habitable zone for a long time (where water is a liquid), probably toward the end of the habitable period. The Drake Equation reflected the belief of its developers that civilizations would last either a short period of time, less than a thousand years, or a very long time measured in the hundreds of millions of years.

Interwoven throughout the book are historical comments about politicians and when they first were initiated to climate change. Lyndon Johnson, briefed on the issue by Charles

Keeling and Roger Revelle, included a comment about the need to reduce carbon dioxide and fossil fuels in a joint session to Congress in 1965.

Carbon dioxide is part of a great cycle: volcanos put it into the atmosphere, weathering breaks rocks down that bind with it into carbonate minerals, rocks are subducted below the surface, melt, and the cycle repeats.

Biodiversity is often taught using a two-actor predator-prey model, but it turns out that predators overshoot so are still multiplying when the prey population has begun to shrink. This makes it more likely that predators will collapse as if they walked off a cliff after enjoying a strong growth period. This is believed to be what happened on Easter Island as the population eventually exceeded the island's carrying capacity and reminds me of the growth period we are enjoying today. I worry that we will pass a tipping point without recognizing it.

Venus shows what happens when feedback loops lead to a full-blown greenhouse effect. Planets seek an equilibrium temperature. Earth would stabilize at about 0 degrees Fahrenheit based on its distance from the sun. Swedish Nobel Prize winning chemist Svante Arrhenius linked the greenhouse effect to coal burning in 1896. On Venus, without an atmosphere, water evaporated. Hydrogen escaped into space, leaving oxygen and creating a positive feedback loop. Carl Sagan showed how energy became trapped by carbon dioxide, warming the planet.

On earth the atmosphere has a cold layer that causes water to condense and return to the ground as precipitation. This allows negative feedback loops to counteract and stabilize the cycle. Higher temperatures lead to more evaporation, more rain, more weathering, more carbon dioxide captured by rocks and subducted. This is what is happening today, with the Earth trying to self-regulate. In past biodiversity events, when great extinctions occurred, the amounts of carbon dioxide in the air changed too fast for this process to reach a steady state without major changes. The concern today is that the Anthropocene era may be our last.

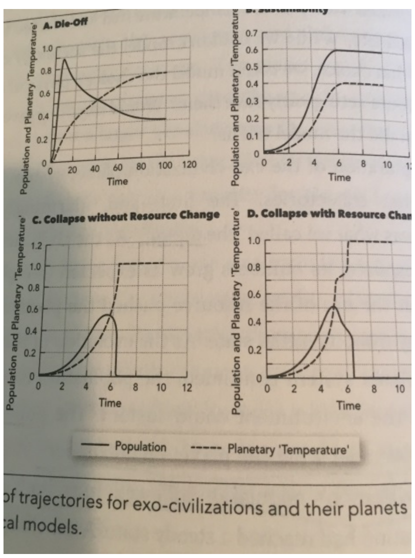
Mars has its own unique story. With little atmospheric pressure, any water present boils away once it reaches the surface. It does appear there is water present, but sealed below the surface. Because Mars is spinning on its orbit, similar to other planets, trade winds form to move energy from the equator to the poles. Models used on Earth are tested on Mars since there are fewer variables. Daily heat fluctuations impact the pressure.

Mars had flowing water on its surface, but has not for over 3 billion years. It's not known how it was lost. Its previously habitable state is gone and its atmosphere is mostly carbon dioxide.

Sustainability is a special state of habitability. Both Venus and Mars have carbon dioxide atmospheres, but the planets could not be more different. Why? Is it as simple as the energy absorbed by a planet closer to the sun versus one farther away?

The Earth has enjoyed 10,000 years of relative calm relative to temperature, conveniently aligned with the Holocene era of humans. The previous 10,000 had been much more volatile, and colder by as much as 80 degrees (as measured in Greenland).

Using planetary temperature as the driver, a model looked at population interacting with temperature and the planet's constant movement toward a steady state. With assumptions made to simplify the results, including a switch to renewable energy once the planet warmed, results fell into three general options. In the "die-off," population overshot and reduced until a steady state was restored. Some of these scenarios resulted in 70% deaths, more than Europe experienced during its Black Death period in the 14th century. A soft landing scenario resulted from early transition to renewable energy. In the full blown collapse scenario, the speed of change was too fast to reach a steady state prior to humanity's demise. Randomness is present in the system. Some simulations resulted in collapse even after switching to renewable energy in an early duration.



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