CAHIERS
FRANÇOIS VIÈTE

Série III – N° 7

2019

La fin du monde,
de la théorie à l'expérience vécue

sous la direction de
Frédéric Le Blay

Centre François Viète
Épistémologie, histoire des sciences et des techniques
Université de Nantes - Université de Bretagne Occidentale

Imprimerie centrale de l'Université de Nantes
Octobre 2019

Cahiers François Viète

La revue du *Centre François Viète*
Épistémologie, Histoire des Sciences et des Techniques
EA 1161, Université de Nantes - Université de Bretagne Occidentale
ISSN 1297-9112

cahiers-francois-viete@univ-nantes.fr
www.cfv.univ-nantes.fr

Depuis 1999, les *Cahiers François Viète* publient des articles originaux, en français ou en anglais, d'épistémologie et d'histoire des sciences et des techniques. Les *Cahiers François Viète* se sont dotés d'un comité de lecture international depuis 2016.

UNIVERSITÉ DE NANTES

ISBN 978-2-86939-250-8

SOMMAIRE

Cahiers François Viète, série III, 7, 2019, p. 71-93

Scientific Doomsday Scenarios: Foresight Projections for the Near and Deep Future

David Baker*

Résumé

Cette contribution interroge les projections relatives à la fin de la Terre et à la destruction de l'Univers par la chaleur, en lien avec le récit scientifique de la Big History. Elle introduit également quelques concepts issus du champ de la prospective consistant à envisager les différents futurs possibles selon une approche méthodique et classificatoire qui ne relève pas de la pure spéculation. De tels concepts rendent possible la réflexion sur le destin potentiel de l'humanité sur une échelle de 100 à 200 ans. Après avoir étudié l'issue probable dans le futur proche (aussi bien encourageante que désastreuse), l'article s'avance pas à pas dans le futur lointain. Il s'achève sur quelques réflexions philosophiques prenant appui sur les concepts scientifiques.

Mots-clés : Big History, prospective, destruction par la chaleur, futurisme, complexité, anthropocène, creative descent, effondrement, apocalypse.

Abstract

This paper conveys the projections for the end of the Earth and Heat Death of the Universe according to scientific narrative of Big History. It also introduces some concepts from the field of 'foresight' regarding how to look at multiple futures in a methodical and regimented way rather than speculating wildly. These concepts allow some discussion of the potential fate of humanity on the timescale of 100-200 years. After looking at the potential outcomes of Near Future (both encouraging and disastrous) the paper moves step by step into the Deep Future. It closes with some philosophical reflections rooted in scientific concepts.

Keywords: Big History, foresight, feat death, futurism, complexity, creative descent, collapse, apocalypse.

* Department of Modern History/Big History Institute, Macquarie University (Sydney, Australia).

The thematic focus of the Atlantys conference was to explore the "end of the world" in all its cultural and disciplinary contexts. As a scholar in the interdisciplinary field of Big History, which explores broad trends in the history of the Universe from the Big Bang to modern day, it fell to me to discuss the end of the world in a scientific context and introduce the principles of foresight which we have also incorporated into Big History (Christian, 2004; Spier, 2010; Baker, 2019). Rather than exploring a mythological or religious depiction of the end of the world, I delivered a talk on the possible obliteration of the human race, the death of the Earth and Sun, and the ultimate Heat Death of the Universe. While the initial presentation was a brief 20 minute rundown of the secular scientific future for an unfamiliar interdisciplinary audience, this paper will attempt to unpack what was said in more detail.

Big History is a field that researches broad patterns in deep time from the start of the Universe to the present. It involves experts from across the natural and social sciences (a research cadre including cosmologists, geologists, biologists, archaeologists, historians, economists, and much more) to craft a scientific knowledge as a narrative. Big History began in the 1980s at Macquarie University, Harvard University, and Moscow State University. Each origin occurred independent of the others, and they arose independently because the timing was simply right. For the first time, thanks to scholarly breakthroughs from the 1950s to 1980s, it was possible to assign accurate dates to everything cosmological, biological, and human. Gradually these universities linked up and were joined by others to form a research community and a teaching network that now manifests itself in thousands of primary, secondary, and tertiary education classrooms worldwide. The Big History Institute at Macquarie University is now leading the charge in the field's research and pedagogy.

Central to the unifying patterns of Big History is the concept of complexity: a measurable set of phenomena that includes systems as simple as stars to systems as intricate as living cells or entire societies. In short all the "stuff" out there that isn't just space or weak radiation nearing Absolute Zero. Anything with energy flow, anything with structure. Looking at the Universe with this wide lens, we can see a pattern. Energy flows and structures have been intensifying in tiny pockets of an increasingly cold Universe. Increasing complexity is a common thread that unites 13.8 billion years of history, and places human history in direct sequence with the tooth and nail of biological evolution and the slow churning of stars and galaxies. It is a pattern that tells us the history of everything. By studying how complexity rises, we understand how stars, the biosphere, and humanity have continued to thrive. By studying how complexity falters in a star, species, or society, it tells you a lot about how things die. In essence, if you understand how complexity behaves throughout Big History, you can have a reasonable grasp on how it might behave as it continues to increase in the near and deep future. But ultimately everything dies, and so complexity also tells us a lot about how the history of humanity, the Earth, and the Universe will end.

The near future and the possible obliteration of humanity is difficult to forecast, given it largely depends on the actions of such a chaotic and complex system like human society, with billions of variables and moving parts. And therefore billions or trillions of slightly or drastically varying outcomes. The field of foresight is still able to illuminate those outcomes for the next 100-200 years and classify them within four broad scenarios. We shall discuss the thinkers behind that framework later in this paper. But the deep future on the timescale of billions and trillions of years is easier to forecast because it is driven by the decidedly less complex and more predictable forces of physics in the inanimate cosmos (which in turn make predictive science possible in cosmology). With current data, we have a fairly good idea of when the Sun is going to die, and furthermore when all matter of the Universe will decay back into energy (Adams & Laughlin, 1997). The data could be updated, which may change what we forecast in the deep future, but for now I will deliver an account of what is currently deemed likely to occur.

The purpose of looking into the future on long timescales in Big History is that the outcome of all things can tell you a lot about the overarching patterns and trends that have carried us thus far. Whether we are looking at the trajectory of the human race after 300,000 years of our history, or the thermodynamic trajectory of the Universe itself, by peering into the distant future we learn much about the distant past, and vice versa. Nor is this future one merely of scientific curiosity, since it influences us a great deal philosophically. Where we are likely to end up can have a profound influence on how we view ourselves and what we consider worthwhile human endeavours in the present. Perhaps even driving us to question whether or not there *are* any worthwhile human endeavours in the present.

Foresight

Foresight is a mixture of a science and an art. It relies on our understanding of current scientific data and consensus, and also the strict and disciplined methodology of science to keep our speculations in order. That said, it is inescapable that when predicting the future one will require a large amount of intuition and imagination – which is what makes it an art. But tight methodical reins must be kept around these artistic elements in order to avoid the exercise growing disorganised. You must not predict one future. You must predict *several* futures. And then assess each scenario based on their plausibility.

These multiple futures, regardless of their content, fall on a spectrum (Voros, 2009). Futurists have been developing a method of classification for each future scenario for over forty years (Amara, 1974). I employ the model refined by fellow big historian, Joseph Voros (2003). During a standard survey of the future, one may start with the most plausible or probable scenario, but in order to properly account for contigency, one needs to branch further out to see the other variations of decreasing levels of plausibility. At the very edges of this spectrum of scenarios are those where we cannot exactly imagine how they could be brought about, i.e. they require knowledge we currently do not have, or they seem to defy our own current knowledge of the Universe. The model has been described as a cone created by a spotlight, where the most probable sits in the middle, but with other scenarios around it being illuminated (Hancock & Bezold, 1994).

Within the field of Big History, this multiple futures methodology is what I use to trace where long term trends we study over 13.8 billion years of the Universe (increasing complexity) or 300,000 years of humanity (collective learning, i.e. knowledge accumulating generationally) where may go in the future. It is a staple of the Big History genre to spend some time analysing the Near and Deep Future after surveying the grand narrative of the past. This methodology allows for more systematic study of the future than the binary between environmental apocalypse and the author's prescriptions to avoid it that typifies much of Big History work (Christian, 2004, p. 459-481; Brown, 2007, p. 230-248; Spier, 2010, p. 189-205; Christian, Brown & Benjamin, 2014, p. 259-301, Christian, 2018, p. 259-301). Or the fatalism that surrounds the end of complexity on the longest possible timescales. As such this methodology, or one like it, is indispensable to our narratives of the future (Baker, 2019).

For my presentation at Atlantys and for much of my work in Big History I have boiled the classifications of the future down to the essential four. There are others, such as the "preferred" future, which is the scenario that the analyst finds desirable, or the "predicted" future, which is simply the scenario an analyst claims will happen. The former is an area that can generate bias on part of the analyst, the latter is quite a reckless thing to do in strategic foresight, and as such very seldom is anyone so bold. After all, the only truly predicted future scenario is the one in which some, if not all, of our predictions turn out to be wrong!

More fundamental to analysis are the following four. Number one is the projected future. Here things play out how current trends suggest they play out. It is "business as usual" where we assume no major change to variables or behaviours, and no dynamic discoveries. The projected future may not even be the most likely future, since new discoveries and changes in variables do eventually occur, but it forms an important baseline for our forecasting. For instance, a projected future would involve the outcome of greenhouse gas emissions and global industrial growth continuing at current rates.

Number two is the probable future. Where variation or change within the bounds of known science indicates where trends might go. For example, if the current rate of population growth on a graph is a projected future, then the low and high lines for changing rates in growth are probable futures. The probable future is the projected future's "margin for error" or "margin for variation". Change can occur but not beyond what science knows *for certain* could happen. So a world takeover by Artificial Intelligence or a commercially viable transition to nuclear fusion do not go in this category, because we have not fully discovered how those things would successfully work yet. Instead a probable future refers to something that science already understands but hasn't yet come to pass, e.g. a transition to and heavier reliance upon solar technologies and lesser reliance on fossil fuels.

Number three is the possible future. Where a discovery yet unknown to science alters a future outcome. This classification is useful because big historians are not visionary engineers capable of predicting technological progress 200 years from now. One could imagine how difficult it would be to predict the existence of the internet in 1800 CE, or its societal effects. A possible future allows us to investigate outcomes without knowing all the details of the causes. It has an unknown variable like an algebra equation: "present + x = outcome". In fact, like an algebra equation, we can use the known variables to get a clearer picture of what the value of x actually is. Major advances in AI, or nuclear fusion, or the majority of "singularity" or "threshold" moments would fall into this category.

Number four is the preposterous future. Where an outcome seems to openly defy the laws of known science, contradicting all available data or understanding. It plays an important role in prediction because it clearly defines what a possible future is by mere contrast. It also forms an important category for mind-blowing leaps forward that analysis does not anticipate. Given the many astounding forms of emergence in Big History, from the origins of life from inanimate matter to the many technological breakthroughs of humanity, seemingly preposterous things do happen. The moon-landing might have seemed preposterous to someone in 1800 CE before rocketry or even human flight. In fact, on a long enough timescale, complexity can turn the preposterous into the possible, then the probable, and even projected. If nothing else, the only way to figure out the limits of the possible is by going beyond them to the impossible (Clarke, 1962).

To sum up the four categories even more succinctly:

- *Projected*: what science says is happening
- *Probable*: what science says could happen
- *Possible*: what science might discover
- *Preposterous*: what science says won't happen

As mentioned in the introduction, it is easier to predict what will happen in the deep future than the near future. The reason why it is easier to predict the future on the timescale of millions, billions, and trillions of years, is we know the physics and how the Universe behaves at large scales. We can estimate how much fuel the Sun has. We can estimate how long it will be before all matter decays back into energy. All that cosmology largely falls into the *projected* and *probable* futures.

At the present we have fairly reliable predictions on how long the Sun will live or when the Universe will die. However, if the Universe were expanding faster than we know to the point that the atoms of galaxies were ripped apart before they could decay, then this new discovery in our knowledge makes the Big Rip (instead of the Big Freeze) a *possible* future (Caldwell & al., 2003). If tomorrow the Universe transformed into a giant rabbit, or if humans learned to defy the 2nd Law of Thermodynamics, that would be a *preposterous* future.

Conversely, the Near Future is much more difficult to predict because we are looking at much more complex systems than the inanimate Universe. Biology and culture. Way more variables and contingencies. A way faster pace of change (Baker, 2015). It is why forecasting the next step of cultural evolution and human history is pretty difficult. But it also is what makes cultural evolution and human history such a great catalyst for rapid and unforeseen change. If any preposterousness is likely to arise it will be here. Even potentially altering the natural projected future of the Earth and Universe if such complexity continues to grow in power and intensity (Baker, 2019).

Analysing the Near Future

Even though the events of the next century are difficult to predict, all the possible outcomes of the Near Future over the next 100-300 years fall into four broad categories. These were conceived by James Dator in an attempt to allow for a structured survey of where society might go in the future based on whether it continues to grow unabated, reaches equilibrium in order to ward of disaster, is gradually unravelled to avoid disaster, or will in fact encounter a disaster (Dator, 2002). From these four directions for the future of human society (up, straight, slowly down, rapidly down) without being further cluttered by detail, we allow a wide diversity of scenarios to be slotted into those broad categories. The purpose of this model is for greater organisation to aid in analysis of plausibility, despite the vast array of different possible outcomes.

In terms of the connection to Big History, the four categories relate to whether human complexity rises, stabilises, gracefully decreases, or collapses (Voros, 2013; Chaisson, 2001). Throughout human history, there have been major breakthroughs and a gradual building of smaller innovations, that in the blink of an eye in terms of evolutionary time have raised the complexity of human societies. Either in terms of structural intricacy of the human web, or in raw terms of the thermodynamic density of energy flows that creates, sustains, or increases all forms of complexity in Big History (Baker, 2015).

Please note that the purpose of these categories is not to make any definitive statement about the future, but they exist for purposes of organisation. There will be some observers who will wish to blur the line between the categories, or replace them entirely, and modification is the prerogative of any analyst coming from any discipline and body of research. But in order to have a fairly well organised approach to the Near Future, one needs to be able to group together the potential thousands of varying scenarios in some form of classification by their common characteristics. In Big History, the Dator model works most effectively given how well it dovetails with our unifying theme of complexity. The four categories for the Near Future are as follows:

Technological Breakthrough – where human society does not hit a limit to its current modes of production in the next 100-300 years and rates of innovation keep pace with growth of the human complex system. Innovation has on hundreds of historical occasions fallen behind the growth of the human system only for society to struggle or collapse until a breakthrough lifts the limits on human growth once again (Baker, 2019). These limits to growth may be imposed by overpopulation, or contemporary modes of production degrading the environment, and many other possible factors. A technological breakthrough can lift the lid on growth, the most dynamic and notable being the first adoption of agriculture c.12,000 years ago, or industrialisation c.200 years ago. There are of course less dramatic innovations that also "lift the lid" such as the proliferation of legumes and four-crop rotation in 17th and 18th century Europe. But in this particular category for the Near Future, the "technological breakthrough" is confined to the most notable and dramatic thresholds analogous to the impact of the rise of agriculture or industrialisation on human lifeways and complexity.

Whatever the next breakthrough, complexity continues to rise, perhaps even dramatically. This broad category would include all scenarios that involve a major jump in energy use, production, or a major threshold moment in increasing complexity. Perhaps it involves the economically viable distribution of nuclear fusion power, making energy cheap enough even for the poorest countries to develop, with an exponential increase on the limits of energy and production globally, and without the corresponding degradation of the biosphere that comes with fossil fuels. But such a breakthrough also includes those scenarios where humanity hands the reigns of future complexity to a completely different system or entity (such as in multiple scenarios with AI) resembling the shift from biological evolution to collective learning being the main driver of increasing complexity. I have previously likened the shift from biology to culture to a highway overpass looming over older roads (Baker, 2015, p. 103) and would liken the shift from culture to AI to airplanes soaring 30,000 feet over the highway. There is a presumption in this category that structural complexity will increase, as will the average Free Energy Rate Density (*erg/g/s*) of human society. The latter of these is the only quantifiable metric we currently have for complexity devised by Eric Chaisson, and employed by multiple big historians including myself (Chaisson, 2001, 2013). As a result of these breakthroughs, human complexity (structural or thermodynamic) is symbolised by the arrow pointing up.

To be even more succinct, a major revolution in technology "saves us at the 11th hour" and allows humanity to continue to produce, develop, and grow and similar or higher rates without the present danger such rates present to the environment and the global population overall. It is a neceessary category to contain all the plausible and implausible "miracle cures" to the current predicament humanity finds itself in the 21st century stemming from the continued acceleration of technology and scientific progress.

Green Equilibrium – where human society over the next 100-300 years does not develop a "singularity" or major technological breakthrough in the Near Future (by no means a guarantee since the first agriculture and Industrial Revolution are over 10,000 years apart) and live within their means to avoid total degradation of the biosphere. This may include technological innovation at a smaller scale along with some good planning, government policy, and a shift to more sustainable forms of production. Human complexity does not increase significantly but does not decrease either. The defining characteristic is equilibrium.

Instead of waiting for a brilliant set of inventions saving humanity at the 11th hour and to be free to continue developing our economies at the same or higher rate, this category presumes some tightening of consumption and production to environmentally sustainable levels. In a way this category resembles theories in environmental economics about "prosperity without growth" (Jackson, 2009; Brown, 2015). The object of this carefulness is to avoid the exhaustion of the human complex system and the Earth, and a decline of complexity analogous to a star burning out its fuel, a species overpopulating an ecosystem, or an agrarian society hitting the population carrying capacity.

For those analysts who would be skeptical of a purely technological solution to the 21st Century Crisis outlined in the first category, the second category of Green Equilibrium presents mixture of technological and non-technological solutions. These may be innovations in doctrine, policy, or method. Or they may involve a cultural shift. Or they may harness existing renewable technologies in a more efficient way. As such this scenario incorporates a great many "mixed" solutions that involve some form of conservation and sustanabile behaviour, as opposed to breakthrough and a relatively unrestrained rate of growth. This category also contains the majority of prescriptive solutions or "positive" futures outlined in major works in Big History (Christian, 2004; Brown, 2007; Spier, 2010; Christian, Brown & Benjamin, 2014; Christian, 2018). One suspects this is the case for the prescriptive or positive future outcomes discussed in other fields. Since complexity neither dramatically increases nor dramatically declines it could be symbolised by the arrow pointing straight forward.

Creative Descent – where human society is in danger of exhausting the Earth's ecosystems with potential blowback on human society, and so invokes a form of environmental policy that actually reduces human production and consumption in order to ward off disaster. It is a deliberate unravelling of human complexity. Examples of scenarios within this category include radical population control and reduction, dismantling of heavy industry, restrictions on car and air travel, restrictions on energy consumption and production rather than their replacement with renewable forms, rationing of food and clothing, etc. This category can be temporary or long-term. Over a long enough period of descent, human complexity (whether structural or thermodynamic) more closely resembles the agrarian civilisations of 300 years ago than society today. It is a conscious retreat of complexity from the limits of the Earth (temporarily or permanently). It is a decline of complexity without collapse symbolised by an arrow going gradually down.

The purpose of this category is to contain all scenarios (whether mostly positive or negative in tone and presentation) that include humanity "living within its means" but with those means being by necessity significantly lower than current rates of production and consumption today. For example, the restriction on air travel to, say, 10% the current volume in order to reduce carbon emissions. This would have a tremendous effect on people's lifeways and many economies. What makes *Creative Descent* differ from *Green Equilibrium* is that the latter category does not require such drastic reduction, or else would furnish an alternative (e.g. non-emitting aircraft, etc). Some Creative Descent scenarios are not as dramatic and require only slight reductions (e.g. reduction of air travel to 90% of its current volume) but the key feature that it does involve some reduction to reach the level at which society can "live within its means".

Collapse – involving every conceivable doomsday scenario. While most apocalyptic warnings that currently fill most Big History content concern potential environmental disaster, it also includes every manmade and natural cause from nuclear war, to superbugs, to an asteroid impact, to a super-volcanic eruption, etc. The reader is likely to have imagined a few of them. This category covers every scenario where human complexity dramatically declines regardless of the cause. The beauty of this approach is it puts all forms of collapse and doomsday under one banner forming one quarter of the total analysis. This reduces the preoccupation with doomsday that can overwhelm analysis. Instead of the binary of apocalypse-survival, one has four categories to soberly evaluate for probability. The general trend of complexity in this category is rapidly down. And it is here that we encounter our first possible 'end of the world' in keeping with the Atlantys conference theme.

Subtleties of Interpretation

There are some important things to note with these categories. First, that all of them contain potential hardships for the individual humans living through them. While some categories may contain more "negative" scenarios than others, there is not necessarily a purely "positive" category in terms of human well-being. *Collapse* obviously will involve human suffering, as will potentially any draconian measures necessary to achieve *Creative Descent*, even if the resulting standard of living improves in a stripped-down and simplified society a generation or so down the line. But *Green Equilibrium* may also involve telling the developing world currently responsible for 63% of all greenhouse gas emissions to stop industrialising either temporarily or permanently, thus curtailing the increase of their standard of living (LUCF Indicator 2011). And a *Technological Breakthrough* may at first glance seem like the consistently "positive one" but many scenarios may also include individual human suffering. The most obvious example is the numerous scenarios where humans hand the reigns of complexity over to AI resulting in human irrelevance, unemployment, deprivation, starvation, or extinction. An increase of complexity should not be confused with an increase with human well-being, just as the Industrial Revolution sometimes caused a great deal of human suffering with depraved factory conditions, or indeed as the invention of agriculture caused a decline in health and the rise of disease (Christian, Brown & Benjamin, 2014, p. 112-115, 260-262). In fact from the explosions of supernovae, to the bloody tooth-and-claw of evolution built on the brutal death and extinction of millions of species, increased complexity has always engendered some form of destruction and, in latter phases where there is consciousness, suffering. We must not confuse the simple empirical trend of increased complexity we have observed over 13.8 billion years with more Whiggish notions of historical progress (Butterfield, 1931, p. 5-6).

Second, a scenario in one of the four categories may actually lead subsequently to a scenario in one of the other three. For instance, *Creative Descent* could occur 2050-2200 C.E. and then be followed by a *Technological Breakthrough* or *Collapse*. Or a *Technological Breakthrough* may result in a *Collapse*. There is nothing about this system of analysis that locks one particular scenario and one particular category in for the entirety of the Near Future. There is always the possibility of oscillation in terms of whether complexity continues, slows, or reverses, just as it has throughout human history, and more widely in the Big History of 13.8 billion years.

Third, once we start looking at the "Middle Future" on timescales of thousands of years, there is an important point to consider. As long as humanity continues to exist without total annihilation of the human species, it becomes increasingly likely that another *Technological Breakthrough* akin to the first agriculture or modern industrialisation will occur. If we look to past examples of oscillations, in the era of agrarian civilisations c.3000 BCE to 1750 CE, civilisations underwent periods of population decline, pandemic disease, sociopolitical instability, or total collapse (Turchin & Nefedov, 2009, p. 6-20, 303-311). Yet collective learning (the human ability to accumulate more innovation with each generation than is lost by the next) continued to accumulate despite the deaths of thousands or millions. Even in the most extreme cases, where the devastation was so thorough that some collective learning was lost (called a Tasmanian Effect) after a few centuries or millennia the knowledge was generally recouped and surpassed (Baker, 2015, p. 89-92). In a *Green Equilibrium* scenario, human complexity will hold firm along with the general number of potential innovators for collective learning and the connectivity between them. A breakthrough in collective learning is assured (though the timing of this breakthrough is open to question). In a *Creative Descent* scenario, human complexity is deliberately unravelled, but the collective learning required to rebuild that complexity is not forgotten and potential innovators still survive. After a great duration of time, and with the reconstruction of the necessary research and development infrastructure, the retained knowledge could again be utilised and advanced. In a *Collapse* scenario, millions might die but collective learning might be retained. Or in more extreme scenarios a Tasmanian Effect may occur but on a long enough timescale of thousands of years for recovery, knowledge may be rediscovered in a long lost archive or database or simply reconceived. Only in the most extreme *Collapse* scenarios involving the annihilation of every single human being on Earth does the eventual advent of *Technological Breakthrough* become impossible.

Evaluating Feasibility

Concerning the four broad categories of *Technological Breakthrough, Green Equilibrium, Creative Descent,* and *Collapse*, we need a way of evaluating the likelihood of the many scenarios contained within them. In Big History, we are currently developing such a method in a few books, articles, and educational courses. In a framework that forecasts for multiple futures, we are able to assess what degree of feasibility a scenario has compared to the others according to available data. We can then evaluate each scenario either systematically or in wide-ranging discussions with peers, students, and public audiences on the basis of the *projected*, *probable*, *possible*, and *preposterous* futures outlined above.

A Big History treatment of the Near Future in a course or book then involves an assessment of many different scenarios. For *Projected Futures*, the big historian interrogates why current data and trends seem to be heading this way. For *Probable Futures*, the big historian assesses changes within the bounds of realism and current human knowledge would be necessary for those outcomes. For *Possible Futures*, the big historian explores what kind of discoveries would be necessary to achieve that outcome and try to elucidate what that might look like. And for *Preposterous Futures*, the big historian has to justify why those outcomes are so outlandish – even on a long timescale.

Further, classification of different Near Future scenarios and a rating of their feasibility is becoming an area of greater scholarly debate. For instance, many "preferred" future scenarios in major Big History works fall into the category of *Green Equilibrium* (Christian, 2004; Brown, 2007; Spier, 2010; Christian, Brown & Benjamin, 2014; Christian, 2018). It would be interesting to know whether scholars rate these preferred futures as the most likely scenarios. Further, another scholar may come along and rate most *Green Equilibrium* scenarios as *Preposterous Futures* because they deem human nature incapable of maintaining itself at equilibrium or accepting a model of "prosperity without growth" at either an individual or a governmental level. At least not without one of the greatest revolutions in human behaviour in 300,000 years. If a scholar deemed the "preferred" futures of prominent big historians to be little more than pipe dreams, this might kick off a flurry of scholarship in response. Similarly, scholars could discuss whether *Collapse* scenarios are *Projected Futures*, whether *Creative Descent* scenarios are *Probable Futures*, and the extent to which *Technological Breakthroughs* are *Possible Futures*. This part of the field captures more attention, and a full edited volume of dozens of contributions on Big History and the Near Future is being published out of Springer later this year.

The Projected/Probable Deep Future

Analysis of the Deep Future falls within two broad streams. The first stream is the "natural" *projected/probable* futures of the Earth and the Universe, where higher complexity like biology or society have no impact on the processes of cosmology. The second stream is a series of *possible/proposterous* futures where complexity continues to increase for millions, billions, and even trillions of years beyond the current point of human technology on Earth to the point where the wider cosmos are actually affected and manipulated. In my brief presentation at the Atlantys conference, I only had time to run through the first stream for the uninitiated, which I will also do here. Then I will discuss how we can examine the contours of the second stream.

Regardless of what happens to humanity, the actual end of the world is more certain a prediction, flowing from the more regular and predictable laws of physics. Provided we have the right data, we can make fairly concrete assertions and estimates about cosmology at the wider scales. These predictions may shift as data becomes more refined or as physical theories are updated or replaced, and as such the narrative presented below may not remain the same in coming years.

- *1 billion years from now: Death of the Biosphere*

In the "Middle Future" of the next few thousand or million years, it is true that supervolcanic eruptions and major asteroid impacts strike Earth and obliterate a great deal of life every 100 million years on average (Hazen, 2013). But so far they have not yet succeeded in "ending the world", just wiping out a large percentage of existing species.

The deep future is much more certain. In about a billion years, the Sun will begin to exhaust its fuel. It will start to inflate like a dead cow in a wet field. Its luminosity will increase, CO2 levels will decrease, and this means plants on Earth over the following years will find it harder and harder to do most forms of photosynthesis and thus sustain complex life on our tiny rock. Life would struggle and decline from the 1 billion year mark onward (Caldeira & Kasting, 1992). Life has existed on Earth for 3.8 billion years. It has 1 billion years left before decline starts to set in. That's roughly twice the amount of time that separates us from the Cambrian Explosion, but only roughly 25% of the time that life has existed. In a sense, life on Earth has already had its midlife crisis and is already approaching retirement age.

- *3-5 billion years from now: Death of the Sun and Earth*

At the 3 billion year mark, the Sun will grow larger and larger until it boils the surface of the Earth dry. Once we get to an Earth's surface with a temperature greater than 100 degrees Celsius, we can be pretty sure that's it for life on Earth. Perhaps some single-cell organisms could still exist in the cracks of the Earth, but that is a clear decline of complexity and the end of the tale in our biosphere. A few hundred million years later, the Sun will grow so large it will engulf the Earth, burning and absorbing whatever is left. The planet itself will be destroyed. The Sun may also bloat up to destroy Mars. But it will never get so large that it goes beyond that, leaving the asteroid belt and the gas giants largely unscathed (Baker, 2017; Schroeder & Smith, 2008).

The Sun will continue growing, until in about 5 billion years it will shrink back and become a small, dense little star. A shadow of its former self. After a few more eons, it will run out of fuel and snuff out completely. In that sense the Sun is already middle aged. We currently exist at the halfway point in its life. Here is a quite literal and scientifically projected "end of the world". If human beings have evolved meanwhile into some sort of sci-fi super-civilization, we will have long since fled the place of our birth.

- *The next 200 Billion Years: The End of the Golden Age of Astronomy*

As dark energy continues to accelerate the expansion of the Universe past the speed of light, we would no longer get to see the light from other galaxies. If we were to lose the knowledge of Big Bang cosmology, our galaxy would be all we'd see. Or think exists. We'd revert to the idea that the Universe had no start-date, is static, and eternal. The Milky Way would be our entire Universe. That is why a number of scientists refer to the current age where we *can* see evidence for the Big Bang, and *can* see other galaxies, as the "Golden Age of Astronomy" (Chown, 1996; Loeb, 2011).

- *The next 100 Trillion Years: The End of Stars*

All stars have a life expectancy. Giant stars die within a few hundred million years. Middling stars like our Sun last a few billion years. The dimmest, flickering, slow burning stars can last for much longer. Perhaps many tens of billions of years. But like all candles in the Universe, ultimately they waver and flicker out. By the time we reach 100 trillion years from now, there will be *no more star formation*. All the dense hydrogen clouds capable of forming stars will have been used up (Baker, 2017; Adams & Laughlin, 1997). The lanterns will go out. The rubble of the Universe will wander in a cosmic graveyard. An eternal darkness will descend. Nothing but ruins and ashes will remain. Eventually even less than ruins and ashes.

- *The Next 10^{40} Years: Heat Death of Matter*

The average organism lives a few years or decades. The average species sticks around for a few hundred thousand years. The average star lasts a few billion. But these are highly complex arrangements of building blocks. What happens to the building blocks themselves? The atoms? Not only do corpses rot, not only do stars die, but atoms themselves will eventually melt and fade away. This is what will occur in approximately 10^{40} years after the Universe has gone many trillions upon trillions of years in the darkness. Atoms will decay into energy, radiation, which will be stretched out across the Universe like too little butter on a giant slice of bread (Baker, 2017; Adams & Laughlin, 1997).

In Heat Death, or the "Big Freeze", the entire Universe will become an empty orb of weak radiation, cold and dwelling in the darkness, in a Hades made real. At this point there will be little to no energy flows in the Universe. Complexity will cease to exist and will never rise again. It will be physically impossible. All the work of the past 13.8 billion years will be erased as if it never existed at all. A blank eternity, with no change, no events, no history. Not just the end of the world, but the end of our story. The end of all history.

- *The Next 10^{100} years: Evaporation of Black Holes*

The only thing that will remain in the Universe besides weak radiation are black holes. And they will exist for longer only by virtue of the fact that they are so dense that they take longer to dissolve. But they too emit radiation. They too will decay. In 10^{100} years, even they will be gone. Dissolved into nothingness. Even their hum of radiation smeared out into an almost equal distribution of energy. According to the laws of physics as we understand them, this fate is inevitable. This is our projected future. This is the end of things (Baker, 2017).

The Possible/Preposterous Deep Future

There are a few possible/preposterous scenarios in the Deep Future that are entirely natural and do not require the intervention of advanced complexity. An old *projected future* from previous years was the Big Crunch, where it was thought that the gravity of the Universe would eventually stop the expansion and suck everything back in on itself within a few billion or trillion years, where the Universe would end in the fireball it began with. Maybe it would even just repeat the process and set off another Big Bang (Davies, 1997). It gives rise to the poetic idea of death and rebirth on a cosmic scale. However, the scenario is now the least likely. It would require the Universe's expansion to slow down at some point. But the expansion of the Universe is not slowing down, it is accelerating. The Big Crunch falls into the category of a *possible future*, since it would require the revision of current cosmological data.

Another possible scenario is slightly more likely, the Big Rip. If the Universe expands and accelerates more rapidly than it currently appears to be doing, then not onlythe space between galaxies but also the space between atoms within galaxies will grow larger, eventually overpowering the nuclear forces that hold atoms together. Essentially, the Universe would be expanding so rapidly that in about 20 billion years, the atoms of the Universe might actually be torn apart. Complexity would end a lot sooner than the decay of atoms back into energy trillions and trillions of years in a Big Freeze scenario, and a lot more violently (Caldwell & al., 2003). In that sense, it is almost fortunate that the Big Freeze is the *projected future* because it gives the continued life of complexity a near eternity to develop with all the surprising shifts and threshold moments that may occur, as opposed to just 20 billion years. Currently the Big Rip remains only a *possible future*. If further data implies the Universe is accelerating catastrophically fast, the Big Rip will become the *projected future*.

Other possible/preposterous futures involve the increase of complexity and the rise of supercivilisations. Essentially take the accelerated progress of science and technology over the past 200 years and continue it for thousands, millions, and billions of years into the future. While not an entirely unreasonable premise which is worth exploring, it is a bit more difficult to illuminate what such a future may look like.

This article will propose one more methodical system by which we can elucidate the contours of the future. We may not know the details of the highly complex systems, but we can see the direction of the arrow of complexity. If we have a way of deciphering and quantifying what that arrow means, we can construct a semi-algebraic equation about the future, where we have unknown values symbolised by x but also the sum of that equation. This can be achieved by adapting the Chaissonian metric central to Big History to forecast the future (Chaisson, 2001).

Eric Chaisson's Free Energy Rate Density (FERD) is a measurement of the energy flows of a complex system in a certain amount of mass in a certain amount of time (*erg/g/s*). It has been used as a rough metric for complexity in multiple Big History works. The Chaissonian metric has particular value because it strikes to the root of what creates, sustains, and increases all complex systems: flows of energy. Every single star, new element, new organism, or human manufactured product, etc., would not exist without an initial burst of energy flow to create them. Without further energy flows (fuel) a star would die, an organism would starve, and an artificial machine would shut down. And without a further increase in energy flows it is highly unlikely we could make the leap from single-celled life to multi-celled life, or from an agrarian to an industrial society. Hence the intensification of free energy rate density concurrent with the rise of complexity in Big History.

System Complexity (ranked from lowest to highest)	*Free Energy Rate Density (erg/g/s) (Averages)*
The Milky Way	0.1
The Sun	2
A Red Giant Star near to supernova	120
Algae (photosynthesizing)	900
Cold-Blooded Reptiles	3000
Warm-Blooded Mammals (average)	20,000
Australopithecines	22,000
Human Foragers (average consumption)	40,000
Agricultural Society (average consumption)	100,000
Industrial Society (average consumption)	500,000
Modern Society (average consumption)	2,000,000
Estimates for Future Kardashev Civs, carrying on from Modern Society Average (Baker):	
Type I Civ (Planet)	2,600,000
Type II Civ (Star)	70,200,000,000
Type III Civ (Galaxy)	14,000,000,000,000,000,000,000,000
Type IV Civ (All galaxies)	6,000,000,000,000,000,000,000,000,000,000,000,000
Type V Civ (All universes)	Above x 10^{500} sets of physical laws multiplied by slightly less than an infinite number of universes with those laws

Figure 1 - Complexity Average based on Free Energy Rate Density (Sources: Chaisson, 2001, 2013; Baker, 2019b)

A quantifiable metric for complexity that demonstrates an increase of numerical values for complexity during its cosmic evolution over 13.8 billion years is useful for projecting further increases in complexity in the future. Particularly once we start taking averages for human societies. Any metric that relies on a quantifiable pattern and takes us beyond short-term speculation is an improvement in how big historians approach the question of the future.

For the rest of this paper, let us conduct a simple thought-experiment, aided by some simple arithmetic to gain an impression of a *possible/preposterous* Deep Future in which complexity continues to rise. Please note I do not make predictions as to when any of the major thresholds outlined below will occur, but simply supply a very wide and feasible window of time in which each of them could occur. To start, if we take the FERD average for modern society as a baseline, we can project into the future for a potential *Technological Breakthrough* scenario. In this scenario, we will temporarily assume the breakthrough establishes humanity as a Type I Kardashev civilisation (Kardashev, 1964, p. 217-221). That is to say, a society that controls the equivalent of all the energy flows of a planet. Currently humanity can be estimated as a 'Type 0.7' (Sagan, 1973) to 'Type 0.75' Kardashev civilisation, allowing for the nearly 40 years increase in energy capacity. That is *not* to say that a breakthrough will allow humans to control 100% of the planet's energy flows, from wind power to the geothermal energy from deep in its core. Instead it is the *equivalent* of the energy flows of an entire planet to give us a realistic FERD value to assign to technological progress over the next 100 to 1000 years (depending on whether delay is imposed by some global disaster or a failure of human society). That brings the average FERD of human society up to approximately 2.5 to 2.6 million erg/g/s to sustain its own complexity.

We now have a FERD score as a baseline with which we can run some fairly simple numbers from cosmology. Let us say human or post-human innovation continues to advance and accelerate anywhere on the timescale of hundreds to millions of years and leads to society being a Type II civilisation, harnessing the equivalent of the energy of a star. It would increase our average FERD to 70.2 billion (if we calculate what fraction of the Sun's radiation is captured by the Earth, harnessed by the biosphere, harvested by humanity, and simply add in the rest). This far outstrips the increase of complexity of anything that came before it (see Fig. 1). We are talking about a nearly godlike civilisation that is probably transhuman, and capable of the most extreme forms of manipulation. Perhaps intricate changes at the quantum scale, perhaps even manipulation of the fundamental forces of the Universe themselves.

If we increase in FERD to the level of a Type III civilisation, or one that controls the *equivalent* energy flows of all the stars in a galaxy, complexity would experience even more phase-shifts (Voros, 2018). Simply multiply a Type II civ by, say, 200-400 billion stars, and you get huge FERD values of 14-28 septillion for a Type III civilisation. When we consider that it might take a thousand to a million years of increasing complexity to achieve a Type II civilisation, and (barring faster-than-light travel) it would take approximately 5-50 million years to colonise every solar system in the galaxy, this is a comparatively short time in terms of 13.8 billion years of Big History, or the roughly 100 trillion years before the end of the Stelliferous Era (Crawford, 2000). Comparing complexity, modern society will look as quaint as a hydrogen atom.

Moving along into realms of even greater preposterousness, a Type IV civilisation that harnesses all the equivalent of energy flows of all the galaxies in the visible Universe increases FERD values into the undecillions with corresponding levels of structural intricacy and environmental manipulation. Essentially the entire Universe is united into one single complex system, with all the corresponding potential for godlike changes being wrought at rapid speed. The corresponding structural intricacy and environmental manipulation is largely beyond the human imagination. Nevertheless, at this point it is a fairly safe assumption that all constraints of the Universe generated by the fundamental four forces of physics, the space-time continuum, or the laws of thermodynamics can be manipulated and/or overcome.

A Type V civilisation that (somehow) unites a theoretical Multiverse into a single complex network involves 5 googolplexes of possible sets of physical laws that would animate those other universes, and an almost infinite number of universe that would come out of cosmic inflation (Baker, 2017). The corresponding FERD and levels of structural intricacy and manipulation are similarly beyond human comprehension. And in order to establish a Type V civ, the constraints of physics would *already* have to be overcome. And the actual effect of increased structural intricacy or environmental manipulation would begin to face diminishing returns in a Multiverse where anything was already possible.

Notably, the ability to travel faster than the speed of light or to break the fundamental laws of physics all fall within *preposterous futures*, and thus so do Type IV and Type V civilisations. At the very least, Type II and Type III civilisations require inventions that are not yet known to science, and so are at the very least *possible futures*. Yet complexity does have a way of making the preposterous possible.

There is one more thing to consider in regard to feasibility. The current *projected future* of the Universe is the "Big Freeze" or "Heat Death". That is, if things continue to proceed with "business as usual" eventually all energy flows will be used up and eventually all matter will decay into weak radiation many trillions upon trillions upon trillions of years from now. With the breakdown of matter in approximately 10^{40} years and the evaporation of black holes somewhere in the neighbourhood of 10^{100} years. A *possible future* is that a "Big Rip" may occur in 20 billion years, if the expansion of the Universe is happening faster than what current data suggests. In these scenarios, whatever happens to biological or cultural complexity has no bearing on the huge inanimate forces that govern the fate of the Universe.

Consider a *preposterous future* for a moment. If levels of complexity continue to increase from our current society to a Type I, II, III, or IV, and this continues to accelerate on the timescale of hundreds of millions or billions of years, then the endgame of the Universe may not be a Big Freeze or Big Rip but a "Big Save". Whereby an advanced super-civilisation has such powers of environmental manipulation that they can stop any natural scenario from happening. And we know the level of environmental manipulation of such super-civilisations would be considerable.

Then we have to ask ourselves, if the pattern of increasing complexity over 13.8 billion years continues somewhere in the cosmos (not necessarily with us) uninterrupted for trillions of more years, will a "Big Save" scenario always be a *preposterous future*? Or one that could gradually transition to *possible*, *probable*, and *projected*? In a "Big Save" scenario, you do not have the same separation between inanimate complexity and animate complexity. Instead, it is the culmination of a narrative where very small and complex systems begin to affect the very large cosmic systems from which they emerged. Perhaps even altering the fate of the Universe itself. In a "Big Save" scenario, the traditional partition between the Near and Deep Future has less importance, because what happens to complexity in the Near Future on Earth ultimately might affect the Deep Future. When considering the fact that the secular scientific projection for the "end of the world" or Universe tends to depress audiences with a grim projection of Heat Death, here is a somewhat intriguing thought that magnifies present attempts at survival in the Near Future. And if you can find a glimmer of hope at the end of the Universe, you can find one anywhere.

References

ADAMS Fred & LAUGHLIN Gregory (1997), "A Dying Universe: The Long-Term Fate and Evolution of Astrophysical Objects", *Reviews of Modern Physics*, vol. 69, p. 337-372.

AMARA Roy (1974), "The Futures Field: Functions, Forms, and Critical Issues", *Futures*, vol. 6, n° 4, p. 289-301.

BAKER David (2015), "Collective Learning: A Potential Unifying Theme of Human History", *Journal of World History*, vol. 26, n° 1, p. 77-104.

BAKER David (2017), "10^500: The Darwinian Algorithm as a New Research Agenda in Big History", in Barry RODRIGUE, Leonid GRININ & Andrey KOROTAYEV, *The Ways that Big History Works: Cosmos, Life, Society, and the Future,* Dehli, Primus Books, p. 175-182.

BAKER David (2019), "Complexity in the Future: Far From Equilibrium Systems and Strategic Foresight", in Andrey KOROTAYEV & David LEPOIRE (eds.), *Big History and the Singularity*, New York, Springer.

BROWN Cynthia S. (2007), *Big History: From the Big Bang to the Present,* New York, The New Press.

BROWN Peter (2015), "Ethics for Economics in the Anthropocene", in Peter BROWN & Peter TIMMERMAN (eds.), *Ecological Economics for the Anthropocene: An Emerging Paradigm*, New York, Columbia University Press, p. 66-88.

BUTTERFIELD Herbert (1931), *The Whig Interpretation of History*, London, G. Bell.

CALDEIRA Ken & KASTING James F. (1992), "The Lifespan of the Biosphere Revisited", *Nature*, vol. 360, p. 721-723.

CALDWELL Robert R., KAMIONKOWSKI Marc & WEINBERG Nevin N. (2003), "Phantom Energy and Cosmic Doomsday", *Physical Review Letters*, vol. 9, n° 7.

CHAISSON Éric (2001), *Cosmic Evolution: The Rise of Complexity in Nature*, Cambridge, Harvard University Press.

CHAISSON Éric (2013), "Using Complexity Science to Search for Unity in the Natural Sciences", in Charles LINEWEAVER, Paul DAVIES & Michael RUSE (eds.), *Complexity and the Arrow of Time*, Cambridge, Cambridge University Press, p. 68-79.

CHOWN Marcus (2010), *Afterglow of Creation: Decoding the Message from the Beginning of Time*, New York, Faber & Faber.

CHRISTIAN David (2004), *Maps of Time: An Introduction to Big History*, Berkeley, University of California Press.

CHRISTIAN David (2018), *Origin Story: A Big History of Everything*, London, Allen Lane.

CHRISTIAN David, BROWN Cynthia S. & BENJAMIN Craig (2014), *Big History: Between Nothing and Everything,* New York, McGraw Hill.

CLARKE Arthur C. (1962), "Hazards of Prophecy: The Failure of Imagination", in Arthur C. CLARKE, *Profiles of the Future*, New York, Littlehampton Book Services.

CRAWFORD Ian (2000), "Where Are They? Maybe We Are Alone in the Galaxy After All", *Scientific American,* vol. 283, n° 1 (July), p. 38-43.

DATOR James (2002), *The Future Lies Behind – Thirty Years of Teaching Futures Studies Advancing Futures: Futures Studies in Higher Education*, Westport, Praeger.
DAVIES Paul (1994), *The Last Three Minutes: Conjectures about the Ultimate Fate of the Universe*, London, Basic Books.
GREER John (2008), *The Long Descent: A User's Guide to the End of the Industrial Age*, Gabriola Island, New Society Publishers.
HANCOCK Trevor & BEZOLD Clement (1994), "Possible Futures, Preferable Futures", *Healthcare Forum Journal*, vol. 37, n° 2, p. 23-29.
HAZEN Robert (2013), *The Story of Earth: The First 4.5 Billion Years, from Stardust to Living Planet*, New York, Penguin Books.
JACKSON Tim (2009), *Prosperity without Growth: Foundations for the Economy of Tomorrow*, London, Routledge.
KARDASHEV Nikolai (1964), "Transmission of Information by Extraterrestrial Civilizations", *Soviet Astronomy*, vol. 8, n° 2, p. 217-221.
LAND USE AND FORESTRY (LUCF) INDICATOR (2011) *Climate Analysis Indicators Tool CAIT 2.0*, Accessed http://cait.wri.org/
LOEB Abraham (2011), "Cosmology with Hypervelocity Stars", *Journal of Cosmology and Astroparticle Physics*, vol. 4, p. 23.
SAGAN Carl (1973), *The Cosmic Connection: An Extraterrestrial Perspective,* Garden City, Anchor Press.
SCHRODER Klaus-Peter & CONNON-SMITH Robert C. (2008), "Distant Future of the Sun and Earth Revisited", *Monthly Notices of the Royal Astronomical Society*, vol. 386, n° 1, p. 155-163.
SPIER Fred (2010), *Big History and the Future of Humanity,* Chichester, Wiley-Blackwell.
TURCHIN Peter & NEFEDOV Sergei (2009), *Secular Cycles*, Princeton, Princeton University Press.
VOROS Joseph
— (2003), "A Generic Foresight Process Framework", *Foresight*, vol. 5, n° 3, p. 10-21.
— (2009), "Morphological Prospection: Profiling the Shapes of Things to Come", *Foresight*, vol. 11, n° 6, p. 4-20.
— (2013), "Profiling 'Threshold 9': Using Big History as a Framework for Thinking about the Contours of the Coming Global Future", in Leonid GRININ & Andrey KOROTAYEV (eds.), *Evolution: Development within Big History, Evolutionary and World-System Paradigms*, Volgograd, Uchitel Publishing House, p. 119-142.
— (2018), "Big History as a Scaffold for Futures Education" *World Futures Review*, vol. 10, n° 4, p. 263-278.