How to Survive the End of the Universe

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The problem of surviving the end of the observable universe may seem very remote, but there are several reasons it may be important now: a) we may need to define soon the final goals of runaway space colonization and of superintelligent AI, b) the possibility of the solution will prove the plausibility of indefinite life extension, and с) the understanding of risks of the universe’s end will help us to escape dangers like artificial false vacuum decay. A possible solution depends on the type of the universe’s ending that may be expected: very slow heat death or some abrupt end, like a Big Rip or Big Crunch. We have reviewed the literature and identified several possible ways of survival the end of the universe, and also suggest several new ones. There are seven main approaches to escape the end of the universe: use the energy of the catastrophic process for computations, move to a parallel world, prevent the end, survive the end, manipulate time, avoid the problem entirely or find some meta-level solution.

*Keywords: Universe, Big Rip, Heat Death, The end of times, eternity, immortality, Big Bang*

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# 1. Introduction

Based on some optimistic models, we could start a wave of colonization of the universe using von Neumann probes moving at near-light speed a few hundred years from now (Stuart Armstrong & Sandberg, 2013), leveraging technology such as nanotech replicators connected to laser-powered sails. Communication and coordination between different parts of such a wave would be difficult. But to prevent some scenarios of the end of the universe, a form of large-scale coordination may be needed. This may take, for example, the form of an aggregation of large masses of matter to build massive astroengineering structures, as described by (Hooper, 2018), who suggested that an advanced civilization will send stars to its central region and increase mass of available matter after expansion of the universe will make these stars inaccessible. (Hooper expected that it may help to increase the available mass by 1000 x, but Loeb wrote that it may be cheaper to migrate to a dense cluster of galaxies (Loeb, 2018)).

Bostrom suggested idea of *astronomical waste* (Bostrom, 2003*)*, a huge opportunity cost which could come into play if we delay our exploration of the universe—as many new stars become permanently inaccessible every day because of the expansion of the universe. He also states that human endowment could be to reach all our opportunities and become everything which we could be. This assumes that we should use remaining time and matter of the universe in the most effective way to get as much human-values-related utility as possible. However, there is another alternative: use all the time and matter available to use to find the ways *to survive the end of the universe*, as the possible prize could be very large: in other words, this enterprise is a form of Pascal’s wager.

Moreover, before the decision about how to fight the end of the universe is made (or at least before we know how much time we actually have left), we need a perfect knowledge of high-energy physics—as we need to know for sure how and when the universe will end and what can be done to prevent it. Gaining such knowledge may require creation of large-scale particle accelerators or long-term observations of changes in dark energy. Sabina Hossenfelder has said that new physics become apparent only by studying energies many orders of magnitude higher than those achievable on Cern’s Large Hadron Collider (LHC), and for example, to study quantum gravity, an accelerator the size of the Milky Way Galaxy is needed (Hossenfelder, 2019).

Several authors have explored the possibility of reaching immortality and surviving “the end of the universe.” Tipler suggested that we will use the energy of the collapsing universe to perform an infinite number of computations in Omega point (Tipler, 1997), but this idea was criticized by (Ellis & Coule, 1994). Many predictions made by Tipler now seem to be obsolete: for example, the mass of the Higgs boson turned to be different than that required by Tipler’s Omega theory, as well as Hubble’s constant. Notably, Tipler wrote his book *The physics of Immortality* before the discovery of dark energy.

Egan suggested—in fictional form—migration into an eternal mathematical universe as the ultimate form of escape in his novel *Permutation City* (Egan, 2010). Dvorsky [explored](https://ieet.org/index.php/IEET2/more/Dvorsky20151209) several ideas about surviving the end of the universe (Dvorsky, 2015). Cirncovich and Bostrom suggested the possibility that a mind could travel between old and new universes via singularities (Ćirković & Bostrom, 2000).

There have also been suggestions about how to extend our existence as long as possible in the case of a Big Freeze. For example, Sandberg et al. suggested an “aestivation hypothesis” (Sandberg, Armstrong, & Cirkovic, 2017), in which civilizations might wait until very cold times to perform computations more effectively. However, such “civilizational life extension” is not a form of true immortality. Along similar lines, Freeman Dyson explored how to survive for a very long time in a slowly freezing universe (Dyson, 1979).

Preventing the end of the universe could be also regarded as a *cause prioritization area* for *effective altruism*, because if we prevent (or survive) some short-term forms of the end of the universe, like false vacuum decay or a Big Rip soon, we could increase amount of good we can create by many orders of magnitude. We could also act effectively in this direction by preventing collider accidents (Kent, 2004) or other potentially dangerous experiments, and by including the goal of surviving the end of the universe in the goal system of future superintelligent AI (Bostrom, 2014). By exploring survival strategies for the universe, we may help establish *existential optimism* for people who are living now, support life extension research, and gain more information from fundamental studies of physics.

Another purpose of the discussion about surviving the end of the universe is to show that *actual immortality* is possible: that we have the opportunity to live not just billions and trillions of years, but for an unlimited duration. My hope is that recognizing the possibility to survive the end of the universe will encourage us to invest more in life extension and prevention of global catastrophic risks. Our life could be eternal and thus have meaning forever. The end of the observable universe is not an absolute end: it's just one more problem the future human race will be able to address. And even at the limited level of knowledge about the universe that we have today, we are still able to offer several dozen more ideas on how to prevent its end. In the distant future, we can find more ideas, choose the best, validate them, and prepare for their implementation.

# 2. How will our universe end, and what does it mean for us?

## 2.1. The end of the universe is not the end of the multiverse or of existence

When we say, “the end of the universe,” we mean the end of the three-dimensional manifold with one-dimensional time with ordinary matter in it, which allows ordered causal connection between states of matter, and thus, uninterruptable computation. This does not mean the “end of existence,” but only some form of transformation of the observable world, one in which computations and memory about previous states become impossible. For example, in the case of the Big Crunch, the universe will collapse into a singularity, eventually followed by a new Big Bang. In that case, all, or almost all information about previous state of the universe will be destroyed in the moment of singularity.

Thus, the end of the observable universe is not the end of the *multiverse*, which is everything which actually exists. This distinction allows theoretical routes to survive the end of the observable universe by sending data to other parts of the multiverse.

The multiverse could be much larger than the observable universe. Theoretical models of the multiverse include different approaches which all assume existence of infinitely large universe which includes all possible things: chaotic inflation, a string landscape with 11 dimensions, mathematical universes, a chain of Big Bang–Big Squeeze. In these models, multiverse consists of many “blobs” of space-time which a relatively stable and causally connected, and in which life could appear.

In this section, we will provide an overview of existing ideas about ways in which the universe could end. There are two main scientific views on the expected end of the universe: the *slow end*, sometimes called a “Heat death” or “Big Freeze”, and several ideas about *abrupt ends* of the universe.

## 2.2. Surviving the end of the universe is not immortality, but it is one step closer

If we—defined here as human-originated intelligence which has at least some of our values—survive the end of the observable universe, we will pass just *one* of the many obstacles to infinite existence. This is analogous to the way in which we will have to find ways to leave the Earth before the Sun engulfs it. In other words, the new world which we might reach after breaking out of this universe could still be finite, and there could be other obstacles to our infinite existence.

## 2.3. A slow end, or heat death

Heat death is not the end of the universe per se, but rather the end of the matter and processes in it. If there is no abrupt end, and the expansion of the universe continues at its current speed, all ordinary matter will decay, black holes will eventually evaporate, and all processes will stop between 10100 or 10200 years from now.

## 2.4. Abrupt end

The choice between these scenarios depends on the geometry of the universe, which is determined by general relativity and—above all—the behavior of an almost unknown parameter: dark energy.

*Big Crunch*: gravity overwhelms the rate of expansion of the universe and it collapses into a singularity.

*Big Rip*: if dark energy is accelerating not exponentially, but quicker, it will reach an expansion speed reaching infinity in a finite time. In one model, this will happen 20 billion years from now, a relatively short time, only around five times longer than time in which life has existed on Earth (Caldwell, Kamionkowski, & Weinberg, 2003).

*False vacuum decay*: If our vacuum is not true vacuum, it could collapse into the state with lower energy, starting from one point, from where a bible of new vacuum will expand with the light speed destroying every physical object (Krauss & Dent, 2008). This theoretically could happen in any moment, but Bostrom showed that the probability of it (or any other cosmological catastrophe) is less than 1 per cent in the next 1 billion years based on our relatively late location on the history of the universe.

*Big Freeze*: the growth of phantom energy stops any movement of particles in the finite time. The idea is explored in the article “Worse than a Big Rip?” (Bouhmadi-López, González-Díaz, & Martín-Moruno, 2008).

*The end of existence*

*Unexistence*: It seems that the universe popped into existence during the Big Bang; in that moment the causal chain of events started. Thus, there is some mechanism in nature which allows the creation of something from nothing. *Unexistence* is a hypothetical mechanism by which the universe completely stops existing. It seems reasonable to assume that if there is a mechanism of appearing from nothing, there should be a symmetrical mechanism of disappearing, which I term unexistence. Hopefully, this can’t happen just in a random moment, as the universe appeared not in a random moment, but in the moment of Big Bang’s singularity or shortly after, during inflation. Thus, the appearance of a new singularity may trigger unexistence.

Another way to (maybe accidentally) cause unexistence is to create an unresolvable violation of the laws of causality, because the Big Bang is also a violation of causality (something appeared from nothing). Logical paradoxes, time travel, or attempts to learn the final theory of everything (or more likely something unimaginable) could cause such causality violations.

*Simulation termination*: We may live in a simulation, and such a simulation could be terminated by its owners. I explored this hypothesis and simulation termination risks in another article (Greene, 2018; Turchin, Yampolskiy, Denkenberger, & Batin, 2019). In this work, we assume that we live in a “real”, unsimulated world.

*Fluctuation ends*: I am a Boltzmann brain and will disappear in the next moment. If BBs are possible, chains of BB-observer-moments seems plausible, and in that case, the end of one BB is, seamlessly, the beginning of another. The problems of being a BB and termination risks are explored in another article (Turchin & Yampolskiy, 2019).

## 2.5. Other limits of existence

*Finite computations*: In the same way, finite existence in time allows infinite computations in the Omega Point theory, infinite existence in time may not allow infinite computations, if, for example, the speed of computations constantly becomes slower.

*Finite reachable space and observable space*: Living in an accelerating universe means that there are fundamental limits on reachable space.

*Finite available matter*: The expansion of the universe means that the total amount of matter which we will be able to reach is limited, and thus the amount of any computations (or the number of beings which could exist simultaneously—or the total size of memory available) is also limited.

*Growth of entropy*: Even if we have access to unlimited energy and matter, we also need a temperature difference to produce useful computation.

*Growth of “computational entropy”*: accumulation of errors, loops, etc. Something similar to age-related changes in the human brain, when it becomes more repetitive and eventually forgetful and demented.

*Eternal boredom*: There are several philosophical articles about how to fight such boredom (Bortolotti & Nagasawa, 2009).

Many of the ideas discussed below may also help to solve these problems.

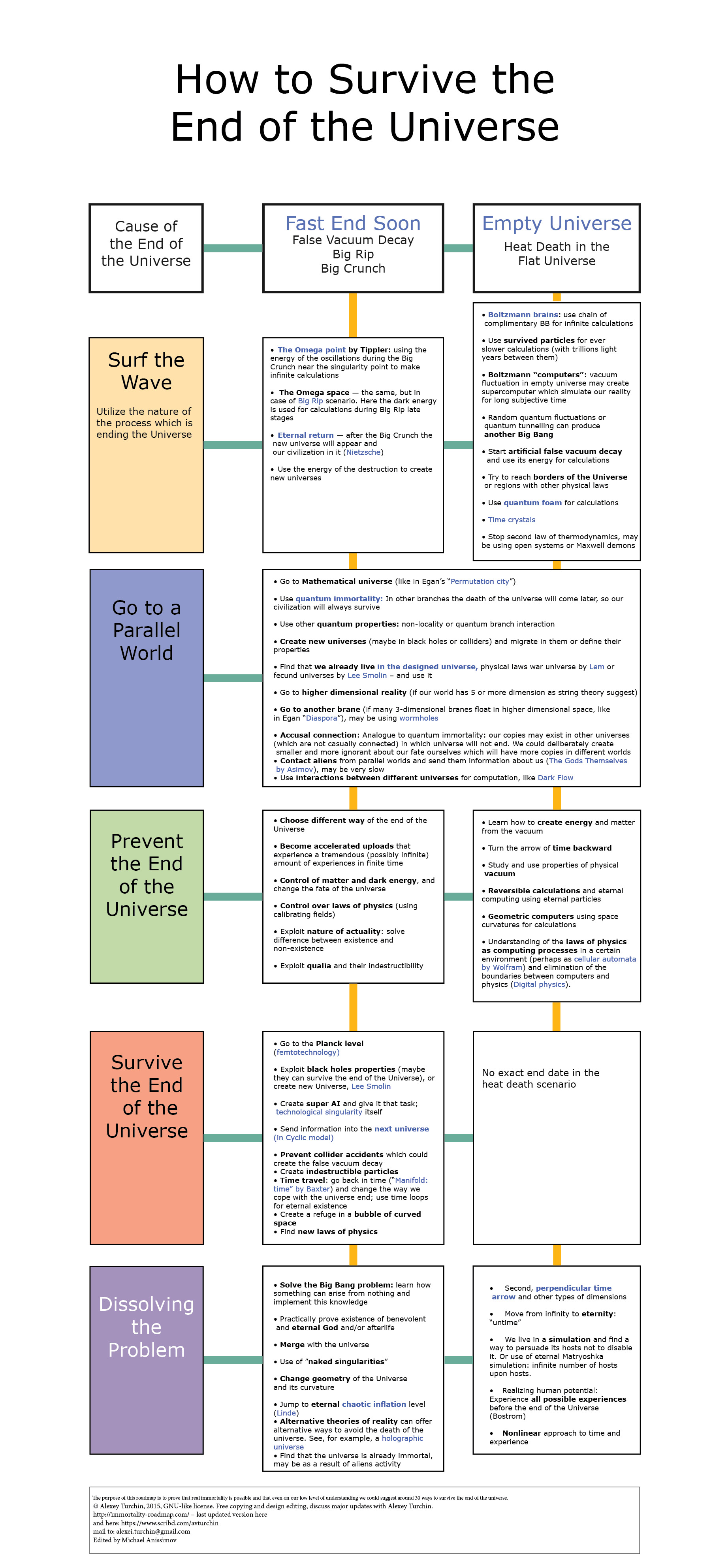
# 3. Overview of ideas about surviving the end of the universe

There are several general approaches to solve the end of the universe problem; each of them includes many subtypes, which will be discussed:

1. *Surf the Wave*: Utilize the nature of the process which is ending the universe for computations. The most well-known solution of this type is Tipler’s Omega Point, where the universe's energy collapse is leveraged to perform infinite calculations.
2. *Go to parallel world.*
3. *Prevent the end* of the universe.
4. *Survive the end* of the universe.
5. *Manipulate time,* thus diluting the idea of the “end”.
6. *Dissolve the problem* (that is, reframe the problem and its basic notion in the way where the problem no longer exists.)
7. *Meta*-*level* *solutions*.

Now we will combine different general approaches with different ideas how the universe will end and will see which concrete ideas go into this classification. An overview of these ideas is presented in Table 1.

Table 1.



## 3.1. Surf the wave: use the process of the universe’s destruction for computation

### For an abrupt end

* *Tipler’s Omega Point*: Use the energy of the oscillations during the Big Crunch near the singularity point to make infinite calculations. Currently, this seems an unlikely outcome, as it requires very fine-tuning of some cosmological parameters, which could be explained only by the final anthropic principle, that is, that the universe is created in a way that ensures the infinite existence of intelligent life. Many of Tipler’s predictions about cosmological constants have been shown to be wrong. Also, most collapsars don’t show oscillations between predominant contraction directions (which is a source of energy for Tipler’s Omega), as they have rotation, which stabilizes most of the matter in one plane, like galaxies. (We can see here how the best ideas about surviving the end of the universe can become obsolete just in 20 years).
* *The Omega Space*: the same as Tipler’s Omega point, but in case of the Big Rip scenario. Here, dark energy is used for calculations during the late stages of the Big Rip.
* *Eternal return*: after the Big Crunch, a new universe will appear, and our civilization will exist again in it (as was suggested by Nietzsche, (Bergström, 2012; Nietzsche, 1883)) or maybe with some variations, in which case it turns out in some form of quantum or big-world immortality.
* *Create new universes from cosmological inflation foam*: Use the energy created by the destruction of our universe to create new universes with predetermined properties. For example, new singularities or new bubbles with eternal inflation. Higher concentrations of energy during the Big Rip or Big Crunch could help make such experiments possible.

### For heat death

* *Boltzmann brains chains*: use a chain of complementary BBs for infinite calculations (Loew, 2017; Mueller, 2017). The empty universe will be not completely empty: it will be filled with random ghosts of quantum fluctuation, which could create observer moments (OM). For any OM there is at least one next possible OM, so there could be illusionary chains of OM, which would subjectively appear continuous, and could be infinite.
* Use surviving particles for increasingly slow calculations (with trillions of light-years between them). Lower background radiation means that the energy required for computations could be even lower than now, so paradoxically, a colder universe could be more effective for computation, as described by (Sandberg et al., 2017).

The remaining matter in the universe could be used to perform ever-slower computation. For example, there will be a period where only atoms of positronium with a size larger than the current size of the universe are present—structures consisting of such atoms will still be capable of performing computations. The main question here is if the total amount of computation will be finite or not after integration over all time until infinity (taking into the account higher efficiency of computations in the ever-colder universe).

* *Boltzmann simulations*: vacuum fluctuation in an empty universe may create a supercomputer which simulates our reality for a long time from the subjective perspective of its inhabitants (Armstrong, 2018).
* *Random quantum fluctuations or quantum tunnelling*: may produce another Big Bang, in which our civilization will appear again, with small, but possibly substantial differences. This is similar to the idea of a Big Bounce and eternal return, but small differences will make the return not identical, and could be used to “explore” different options. This, however, will eventually look like a form of quantum immortality (Turchin, 2018b).
* Start artificial false vacuum decay and use its energy for calculations. In a case of false vacuum decay, enormous amounts of energy will appear on its domain walls. Recent [research](https://medium.com/starts-with-a-bang/could-black-holes-destroy-the-universe-de8a3135856f) on the Higgs boson indicates that smaller black holes could catalyze false vacuum decay (Burda, Gregory, & Moss, 2015). If there is no more energy in our universe useful for computations, false vacuum decay may be started artificially—and the energy of the decay somehow used for computations inside the domain walls. While this approach is very speculative, it is no more speculative than the Omega Point.
* Try to reach borders of the Universe or regions with other physical laws. The end of our universe will follow from its physical laws, but why they should these laws be the same everywhere? Perhaps there are regions of the universe with different physical constants, and thus, a different fate? Starting near-light speed probes could help “us” to reach remote parts of the observable universe, but this is an infinitely small portion of the whole inflationary volume of the universe, so it is unlikely that there will be significantly different sets of physical constants within that range.
* A related idea is to overcome the second law of thermodynamics, maybe by using open systems or Maxwell demons, which would allow infinitely long computations without loss of energy or growth of entropy. Reversible computing (computations which don’t increase entropy) is another idea in this direction.
* Merge with the universe. The universe itself is regarded by some, like (John A. Wheeler, 1990) and (Wolfram, 2002), as a computational process. While the observable, stable universe could end in a violent or a slow death, from another point of view, it is just a form of computation. The idea is to exploit the computational nature of the universe to perform useful computations. This is a rather general idea, and it could be implemented in several ways.

One of such ideas to merge with the universe is the ultimate miniaturization and reaching the level of smallest particles which exist. One of them is smallest pieces space-time which are known as “quantum foam”. Quantum foam is the idea that at the lowest scale the space itself becomes quantum and is in the state of constant fluctuations (it is also similar to the ideas of quantum loop gravity). Another idea is not to merge with the “smallest particles”, but with the laws of physics themselves. As physical laws govern the universe and all “computations” in in, then becoming such a law is equal in some sense to becoming an eternal computer program.

## 3.2. Go to a parallel world

* *Go to a mathematical universe* (like in Egan’s “Permutation City”): If the ultimate reality is mathematical, as assumed by (Tegmark, 2014), creating an everlasting computer, which runs simulations of minds would represent a way to migrate. In this scenario, a physical copy of such a computer is created and then turned off, but in the mathematical universe an infinite chain of the next states of such a computer will be possible, and thus actually exist.
* *Use* [*quantum immortality*](http://en.wikipedia.org/wiki/Quantum_suicide_and_immortality%20): In other branches, the death of the universe will come later, so our civilization will always survive (Turchin, 2018b). Another type of travelling to parallel worlds could be jumping between Everettian branches (Deutsch, 2002). Some of branches could exist longer than another, while all will have eventually similar ends. Moreover, at least some very improbable branches will always survive, and if an idea like quantum immortality is true, there is no need to jump to other Everettian branches; we will (eventually) find ourselves only in those branches which continue to survive, no matter how improbable that survival may be. There is nothing problematic in surviving in improbable situations: think about the very small chance of life arising on Earth or of your birth.
* Use other quantum properties: i.e. use non-locality (Einstein, Podolsky, & Rosen, 1935) or quantum branches interaction (interference) for computations.
* *Create new universes* (maybe in black holes or colliders): migrate to them or define their properties, so our copies are likely to appear in them. This is the idea behind the evo-devo fecund universes described by Lee Smolin, that our universe is optimized via a process similar to natural selection to create new universes via black holes (Smolin, 1992). As our universe is *also* optimized to create intelligent life, we could assume that civilizations are needed to fine-tune this process, perhaps via the accidental (and deadly) creation of black holes in colliders.
* *Find that we already live* [*in a designed universe*](http://www.telegraph.co.uk/news/science/space/7972538/Are-we-living-in-a-designer-universe.html): Gribbin suggests that we could create small universes even now in our colliders, as they are just interiors of small black holes (Gribbin, 2010), but in the future, we could regulate their laws, or even send data inside them. In other words, there are creators of the universe, who more human than gods (and the universe is not a simulation). Lem wrote a short story, “New Cosmogony”, where changes in physical constants could be explained by the wars of invisible civilizations (Lem, 1999).
* *Go to a higher dimensional reality* (if our world has 5 or more dimensions as string theory suggests):If the universe has more dimensions than the three spatial ones we observe, then travel between dimensions is conceivable. The string theory landscape and M-theory assume that there are 11 dimensions, but other dimensions are hidden. In the string landscape, there are could be 10500 or even 10272000 possible types of universe (Susskind, 2003), and many of universes that actually exist could be close to each other in the many dimensional space. While most of the universes may be not suitable for the origin of intelligent life, as they could have different physical laws, they could support existing “technolife”, providing it with new sources of energy and computational media. Each parallel universe could have its own end eventually, but some may have a much longer existence than our universe; travelling between universes could help us to find one that will continue to exist after ours ends. The law of conservation of energy seems to be evidence against the possibility of travel between universes, because if one sends some matter to another universe, it would contradict local laws of conservation. However, we may not need to send matter (in the form of large starships), but only data. Even sending an equivalent of a nanobot or SETI message (Turchin, 2018c) to a parallel universe could be enough to preserve our civilization.
* *Go to another brane* (if many 3-dimensional branes float in higher dimensional space, like in Egan’s “Diaspora” (Egan, 1997)): This might be accomplished by using wormholes to send data (Maccone, 2000).
* *Leverage acausal connection with other universes*: In some sense, this is an analogue of quantum immortality; copies of us may exist in other universes (which are not causallyconnected) in which the Big Rip will not happen. We could deliberately create variants of ourselves smaller and more ignorant about our fate, which will themselves have more copies in different worlds. The simpler the mind, and the more ignorant it is about its location, the more exact copies of it may exist in the universe.
* *Contact “aliens” from the parallel worlds* and send them information about us, as explored in Asimov’s novel [The Gods Themselves](https://en.wikipedia.org/wiki/The_Gods_Themselves) (Asimov, 1972): Even sending a relatively small amount of information, like human DNA, could be the equivalent of survival for *Homo sapiens*.
* *Use interactions between different universes for computation.* It was assumed that gravitation could leak from universe into another, which could explain dark matter observations. While each universe could be finite in time, their interactions could be infinite (or at least much longer).

## 3.3. Prevent the end of the universe

### Prevent a quick end to the universe

* *Choose a different way of the end of the Universe*. If the end is inevitable, maybe we could choose the most preferable one. Maybe we could start false vacuum decay if we have an idea of how to use its energy for computation—or we could mimic Tipler’s Omega Point by jumping inside a black hole. (Actually, we can’t jump inside already existing black holes as we would forever be stuck on the horizon; however, we if aggregate a large amount of matter around ourselves and it starts collapsing, we will find ourselves inside a black hole.)
* *Control matter and dark energy* *and change the fate of the universe*: The fate of the universe mostly depends on the future evolution of the cosmological constant, or dark energy. If we could manipulate this, as we can manipulate all other types of matter we have found (atoms, fields), we may gain control over the future of the universe. The simplest form of such manipulation is manipulation of density and curvature of the universe by moving large amounts of gravitational mass.
* *Control over laws of physics* (using calibrating fields): One theory claims that the laws of physics, or at least some important constants, were fixed shortly after the Big Bang via the random breakdown of some initial quantum fields, called “calibration fields”. Now, it seems that this theory is being replaced by spontaneous symmetry breakdown in string M-theory (Susskind, 2003). Control over such fields would provide control over the observed physical laws, and thus, the laws of nature.
* *Exploit the nature of “actuality”*: Determine the difference between existence and non-existence (Menzel, 2017). Is modal realism true? What is the difference between existence and pure possibility?
* *Exploit qualia and their indestructibility*: Even if the material world is doomed, some “immaterial” elements of it, such as qualia (and numbers), are still indestructible: the green color won’t stop *being* green, even if everything stops existing.
* *Prevent deliberate destruction of the universe*: Some form of an ultimate Doomsday weapon (Kahn, 1959) is conceivable: a party creates a “False Vacuum breaker” and uses it to blackmail all other parties in the universe. While creating such a “Death Star” weapon may be difficult, it is more probable than the random creation of false vacuum decay (if our vacuum is not very fragile). The logic of Doomsday weapons is such that if more than one is created, they could be locked into something like mutually assured destruction (MAD), which makes their firing almost inevitable.

The obvious condition for preventing the end of the universe is cooperation between all sides: space wars (Torres, 2018), or just different approaches to the surviving the universe, could make it less possible, especially if it requires moving large masses, but not escaping into small black holes.

### Prevent the heat death of the universe

• *Learn how to create energy and matter from vacuum*: The law of energy conservation seems to be fundamental, but there are still some controversial ideas about generating energy from vacuum, or other ways to violate this law.

• *Study and use the physical properties of vacuum*:Even if all matter dissolves, vacuum will still exist. It has non-zero energy, all possible things appear as fluctuations, and there could be quantum space-time foam on the Planck level, as well as hidden dimensions of space-time.

• *Reversible computation and eternal computing using eternal particles*: If some particles could exist forever, and if reversible computing turns out to be possible and useful, eternal computation could be possible. However, there are doubts that such computation will actually be useful, as it could be locked into inescapable patterns. This is a starting point of the plot of Baxter’s novel “Manifold: Time”; in that story, a civilization reaches infinite existence in a reversible computer at the end of times but is suffering from the lack of new informational inputs.

• *“Geometric computers” which are using the curvature of space-time for calculations*. In other words, they are using [gravitational waves interactions](https://www.forbes.com/sites/startswithabang/2018/12/15/ask-ethan-are-gravitational-waves-themselves-affected-by-gravity/#1ae4a5c12f3f) to perform computation. [Another idea](https://www.quantamagazine.org/how-space-and-time-could-be-a-quantum-error-correcting-code-20190103/) in this style is that space-time itself is a quantum correcting code.

• *Understanding of the laws of physics as computing processes*:Could take placein certain environments (perhaps as cellular automata (Wolfram, 2002)) and involve elimination of the boundaries between computers and physical phenomena, as is assumed by the field of digital physics (Wheeler, 2015).

* *Use of “naked singularities” as Omega points*: either for computation, as bunkers against the destruction of the universes, or as gates to new universes.
* Change the geometry of the Universe and its curvature. The future of the universe depends on its curvature, which is defined by the density of mass in it according to general relativity. By moving masses, we could change such density at least in some region of the universe.
* Jump to eternal [chaotic inflation](https://en.wikipedia.org/wiki/Eternal_inflation%23Quantum_fluctuations_of_the_inflation_field) level of (Linde, 1983), which, by definition, exist for an infinitely long time. This would involve surfing the wave of the inflationary field for eternal existence.

## 3.4. Survive the end of the Universe

* *Extreme miniaturization*: go to the Planck level ([femtotechnology](https://en.wikipedia.org/wiki/Femtotechnology)) via creation smaller and smaller computers, on which human minds will be uploaded. The smallest objects may be not affected by events at higher levels.
* *Exploit the properties of black holes* (maybe they can survive the end of the Universe). There is a [theory](https://phys.org/news/2011-05-theory-black-holes-predate-big.html) that some current black holes appeared before the Big Bang during previous Big Crunch.
* *Create a new universe with predefined properties using an artificial black hole*, as was suggested by (Smolin, 1992). There should be a way to send a large amount of data to a new universe (at least on the order of terabytes, the size necessary to transfer information about this civilization’s experiences). If there is a way to send such data to a new universe, our universe is unlikely to be the first, and we could find such data from previous universes. One way to code the data is in the numerical values of dimensionless constants or in the fluctuation of cosmic background noise. Finding such noise will be similar to finding a SETI signal (which also includes the corresponding risks of AI-virus attack, or at least the effects of a sophisticated alien culture on our *naïve* culture (Turchin, 2018c)). To start another fecund universe, instruments other than black holes may be more suitable, like control over cosmic inflation and/or initiating false vacuum decay.
* *Send information into the next universe* (in the cyclic model of the universe) (Steinhardt & Turok, 2002).
* *Create indestructible particles as components for computers*: Some particles do not seem to have a half-life, like electrons, and thus could exist for an infinitely long time, at least until it interacts with its antiparticle.
* *Create a refuge in a bubble of curved* *space* (perhaps inside or near a black hole).
* *Travel at speeds above light speed*. This will help us to reach remote regions of the universe where more matter could survive or the end is not so nigh; alternatively, the relativistic slowdown of time in the starship may help some objects survive relatively longer, or could even result in travel back in time.

There is no exact end date in the heat death scenario, so “survival” is not applicable to that scenario.

## 3.5. Manipulate time

The end of the universe is an inevitable event in the future. Thus, escaping the future, by, say, travelling in or manipulating time, may help us to escape the event.

* *Time travel to the past to escape the end of the universe*: Perhaps via a system of wormholes, one of which is moving at near-light speed. Note that there is no need to send actual starships or human beings through the wormhole: a small nanobot or “femtobot” could be enough, or even an information package. For example, if our current civilization observes that a remote “black hole” produces repeated flashes of light (like Morse code), we could download the message. Kardashev spoke about this possibility at the “SETI seminar” in Moscow in 2019 (Kardashev, 2019).

A smaller size for this package means much less energy is needed to create the wormhole, and such a probe would be much more resilient than a larger one. Sending data to the past could cause a “grandfather paradox” (a change in the past which makes a given future impossible), but if the probe is really small, it could have a very small “footprint”. It could be sent to the earlier universe, closer to the Big Bang, where conditions are more favorable for the creation of wormholes, but after it will remain in the “aestivation” to avoid causing a grandfather paradox.

Alternatively, the probe’s goal could be to intentionally cause a grandfather paradox, thus creating an alternative branch of the universe. This could be done again and again, arbitrarily increasing the “subjective time” of existence. An observer would live many times from the beginning of the universe to its end in some kind of loop (or “time-like curve”).

* *Go back in time (as described in Baxter’s novel “Manifold: time” (Baxter, 2003)) and change the way we cope with the universe’s end*: Time travel could help us better prepare to the universe’s end, as we could start preparing from the beginning and know what to do. Even sending a small amount of information about the type of the end and the best prevention strategy will be very helpful if it is sent far enough back in time.

Maybe it is easy to send data not to the present time, but into some earlier universe, like shortly after Big Bang. In that case, the data would need to be preserved until “now” in a way that avoids the grandfather paradox, via some form of aestivation. For example, time-travelling nanorobots from the future could have been present since the dawn of the universe without demonstrating their existence, as that would preclude the formation of life as we know it on Earth. When we are ready, they will show themselves.

* *Closed time-like curves*: or use time loops for eternal existence, either via time machine or near a black hole’s event horizon.
* *Perpendicular time arrow and other types of dimensions*: There are physical theories which assume the existence of two-dimensional time (Bars, Terning, & Nekoogar, 2010). A real-world example of two-dimensional time is the evolution of a novel from one revision to another by its author. In that case, the internal time of the narrative is perpendicular to the time in which the writer makes changes. For example, “Anna Karenina” had 4 revisions by Tolstoy; in each, Anna changes (by becoming a more beautiful woman). As the end of the universe is an event in linear time, moving sideways in the perpendicular time could help to escape it, or at least to “dissolve” the event of “ending” (that is, describe it on another language, where it is not the end). If there are other types of dimensions beyond space and time, they could be also used to escape.
* *Move from “infinity” to “eternity”*: *“untime*”. *Untime*, or existence without change, includes such phenomena as a mathematical universe or pure qualia. As untime is unchanging, it can’t end, but it is very remote from what we could call human life, if we don’t assume some illusion of change within it.
* *A nonlinear approach to time and experience*: Tipler's Omega point is an example of this approach when an infinite amount of experience is generated during a finite time. Some people experimenting with psychedelics claim to be able to experience time dilation or even a stoppage of time, which, of course, would not save them from the end of the universe (or even personal death), but could be an “intuition pump”—showing how an increase in the wideness and intensity of experience could allow a higher net amount of experience to happen in a finite time.

The nonlinearity of time may lead to time loops, internal clock breaks, illusions of timelessness, and travels to perpendicular time.

* *Reverse the arrow of time*: The final anthropic principle, suggested by Tipler, states that the universe is fine-tuned for human existence, as humans are *needed* to survive the end of the universe. This assumes some form of *retrocausality*, where the need to create Omega back-propagates to the past and ensures human existence. This may seem outlandish, but the “ordinary” anthropic principle looks exactly like this: the universe is fine-tuned for our existence and also it is fine-tuned to generate human capability to think about anthropic now (we could observe only those universes where we could think about anthropic).

Another theoretical approach to reversing the arrow of time is to create a state of matter that performs computations not in the future, but in the past (especially if the “past” is not unequivocally defined). This seems to be possible based on the time-symmetry of basic quantum laws, but as the nature of the arrow of time is not known, this approach is still just hypothetical.

* *Turn the arrow of time backwards*: Besides a computer that runs backwards in time, as discussed above, more advanced ideas may be related to finding particles, e.g. tachyons, which move back in time. If we could move back in time, we could postpone encounters with catastrophe.
* *Become accelerated uploads* that experience a tremendous (possibly infinite) amount of experiences in a finite time. Natural “acceleration of time”—in the sense of the number of events per time unit—is probably happening around singularities in collapsing black holes, and is assumed in Tipler’s Omega in the collapsing universe.

## 3.6. Dissolving the problem

* *Solve the problem of the origin of the universe*: learn how something can arise from nothing and implement this knowledge to create new universes with designed properties.
* *Practically prove the existence of a benevolent and eternal God*: and/or afterlife (or that we live in a computer simulation created by an advanced civilization).
* *Merge with the universe*: Reach some form of “practical pantheism” where there are no borders between Self and the outside world.
* *Find that the universe is already immortal*: Perhaps as a result of alien activity.
* *Discover we live in a simulation and find a way to persuade its hosts not to disable it*: Or make use of an eternal Matryoshka simulation: an infinite number of hosts upon hosts. In an infinite nested simulation there is always an upper level of existence (Torres, 2014).
* *Realize human potential*: Experience all possible experiences before the end of the Universe, as was suggested by Bostrom (Bostrom, 2003).
* *Modal realism*: if everything possible actually exists, there is no “end”.
* *Solve ontology*: neutral monism. Find some level of existence where there is no difference between objective and subjective. This is probably the level of qualia.
* “The restaurant at the end of the universe” (Adams, 1978): accept and celebrate the end.

## 3.7. Meta-level solutions

These are solutions that do not specify ways to survive the end of the universe, but offer a credible path to finding the solution.

* Find new laws of physics. The end of the world—as well as new ways to prevent it—follows from the known laws of physics.
* Create superintelligent AI and give it the task of finding a way to survive the end of the universe.
* Prevent collider accidents which could create false vacuum decay.
* Prove that we are in a simulation, prevent its termination, and move to the base reality level.
* Prove that the end is in every next second, and enjoy it. If I am a Boltzmann brain (BB), I will disappear in the next moment, but the same situation has happened in all previous moments I have an illusion of remembering, and this is “ok” (Turchin & Yampolskiy, 2019). There will be a next BB somewhere that will have memories of me now.

The *radical Doomsday argument* suggests the end is in the next moment. It is as follows:

Assumption 1. If the Everettian multiverse exists in the sense of the *many-worlds interpretation*, the number of separate branches is growing exponentially every second, proportional to the number of random quantum events in the observable universe. As there are around 1080 elemental particles in the universe, this means that the number of branches is also growing many orders of magnitude every second. Even if we count only different possible next experiences of an observer, the number will be astronomical, as each different pixel in the visual field could be counted as a separate observer.

Assumption 2. The probability of being an observer depends only on the *number* of observers, but not of the *measure* of an observer.

Conclusion: In that case, a random observer will most likely find herself near some cut-off moment which is most likely to be the end of the universe. For example, if the multiverse branches 1020 times every second, there will be 1020 of my copies in the last moment of my existence compared to just one a second ago. However, if the end of the universe, like false vacuum decay, is itself a probabilistic process, even a high probability of it will be unobservable: there could be some form of *fine-tuning* in which branching and false vacuum decay completely compensate for each other. In other words, if there are 1020 braches every second, but the probability of the false vacuum decay is 1020 to 1 every second, the total number of observers will not change. Moreover, the biggest number of observers in the universe could be located in such fine-tuning regions, as the appearance of a large number of observers every second will not obviate the possibility that a large number will appear in the next second. In such a case, all will eventually “add up to normality” as Yudsowsky [said](https://wiki.lesswrong.com/wiki/Egan's_law).

* *Postpone the end*. Even if the end is inevitable, maybe we could trade one type of end for another; for example, by manipulating dark energy to escape the Big Rip and instead reach a heat death scenario, getting, say, 100 trillion years instead of 20 billion. During these trillions of years, we could find new ways to postpone the end, maybe using energy or the remaining black holes to power our thinking. So, we never actually solve the problem, but just find ways to live longer; this is how things often happen in day-to-day life. Postponing the end might also give us time to find a permanent solution.
* Alternative theories of reality, like a [holographic universe](https://en.wikipedia.org/wiki/Holographic_principle) (where the universe could be completely described by its boundary), can offer alternative ways to avoid the death of the universe. A deeper study of fundamental physics could help us to find new types of “ends” and new survival strategies.

# 4. Preparing for infinite survival

## 4.1. Preventing human extinction before the end of the universe

It seems rather trivial but worth mentioning: if humanity (or our descendants in the form of uploads and AI) goes extinct before the end of the universe, we will not need ways to avoid such an end. However, if superintelligent AI and nanotech appear, and humanity survives most early risks connected with them, there will be rather obvious ways of survival for billions of years (e.g. Dyson spheres, von Neumann probes and space travel) (Bostrom, 2002). Space wars or some now-unimaginable catastrophes could end humanity, even at such advanced stages, but it seems less likely, as the size of the space itself will protect us (barring situations such as an absolute Doomsday weapon, as discussed above).

## 4.2. Choosing between long and very long futures

There is an important choice we must make before the start of space colonization: what are our values and what do we want to do with the universe? If we send von Neumann probes (vNPs) in opposite directions with near-light speed, it will be difficult to reprogram them if our understanding about our goals changes. Thus, we need a better understanding of the fate of the universe and our attitude toward it before we start irreversible colonization of its outer reaches.

This includes an important decision: should we try to get most of the value from the observable universe and accept its natural end—or should we spent most of our resources on a risky bet with a very high payoff: try to find the ways to survive the end of the universe.

## 4.3. Fighting cosmological uncertainty

To make this choice, we must solve “cosmological uncertainty”, that is, learn with high credence what will be the actual end of the universe, how much computation and star travel we can do before it happens, and what our best options and chances to survive it are. In a Wikipedia [article](https://en.wikipedia.org/wiki/List_of_unsolved_problems_in_physics) about unsolved problems in physics, several dozen high-level questions are posted, like why we have the arrow of time, and what the correct interpretation of quantum mechanics might be. It seems that most of these questions will need to be answered before we can know for sure which is the most probable end of the universe.

How long it will take to solve cosmological uncertainty is not clear. Maybe superintelligent AI will appear on a relatively short time scale of around 100 years and will be able to guess everything it needs to know from already available collider and space observation data, or quickly build instruments to gather data and develop an answer. In that case, the final fate of the universe will be known in a few millennia.

Another possible view is that we can’t learn much from local levels of energy and will need very high-energy experiments with Galactic-size accelerators or black holes. The relevant information about the type of the end is, perhaps, just not available here, and we will need to wait billions of years before we can observe small differences in dark energy changes. In that case, fighting cosmological uncertainty will have a significant opportunity cost, as the later we start irreversible space exploration, the smaller the area of the observable universe that will be under our control. This would limit our ability to create astro-engineering constructions to fight the end.

The closer we are to the end of the universe, the more certain we will be regarding its nature and timing, but the less time we will have to prepare.

Also, paradoxically, to fight cosmological uncertainty, we need larger and more sophisticated physical experiments, which, in turn, increases chances of false vacuum decay or other types of catastrophe.

## 4.5. Getting control over large masses and energy

Some ideas about how to prevent the end of the universe assume the need to move large amounts of matter. For example, a large concentration of matter could change local curvature of space. There are some ideas about how to use Dyson spheres to accelerate stars, but this would be a very slow process (Loeb, 2018).

There is only a limited part of the observable universe which we could ever reach. There is an even smaller part within which effective communication with Earth is possible (i.e. sending and receiving data a few times).

## 4.6. Prevent accidental universe destruction

There is a very small probability that we could destroy universe even now by starting false vacuum decay. Small black holes could be nucleation points of new vacuum, and such small black holes could theoretically appear during experiments in a hadron collider. The recently discovered Higgs boson’s mass range renders the vacuum decay hypothesis more probable; also, true vacuum will not be like ordinary vacuum, but will itself gravitationally collapse (Elias-Miro et al., 2012; Mack, 2015). Objections often refer to the fact that much more intensive collisions are happening in the universe all the time; however, there are small differences between collider experiments and natural collisions: the products of LHC collisions have a small relative speed to the Earth as opposite beams collide (Kent, 2004). As a result, it is possible small black holes could have the opportunity to catch surrounding atoms before evaporating via Hawking radiation and could start to grow.

Such a growing black hole would eventually consume the Earth (as in David Brin’s novel *Earth*), but not immediately, as the accretion rate initially could be very slow on the early stages. It may take years before any observable effects became obvious (as the accretion rate could become stable on some lower level and the whole black hole will be just the size of a few atoms, surrounded by a pocket of hot gas and sitting somewhere in the center of the Earth).

However, such a small black hole could exist long enough to make the random event of the false vacuum decay more probable (or maybe two such small black holes would need to collide) (Burda et al., 2015; Villatoro, 2015).

# 5. Survival strategies in relation to other ideas

## 5.1. Order of implementation

Preventing the end of the universe should concentrate on different risks at different times.

1. False vacuum. We need to minimise the risk of false vacuum decay, while simultaneously getting more information about the nature of the universe and reducing our cosmological uncertainty. We should conduct experiments about the nature of the universe carefully, as they themselves may trigger false vacuum decay or have other unintended consequences. Also, if everything possible actually exists, false vacuum decay may be exactly compensated for by quantum immortality, and thus will be an unobservable and inconsequential event.

However, if the speed of the false vacuum bubble is a little bit below the speed of light, we could observe the incoming bubble. For example, if the bubble originates 1 billion light-years from us and has the speed of 99.9 per cent of the speed of light, we would observe, and may be even be destroyed by the radiation of its domain walls.

Bostrom and Tegmark estimated that such type of catastrophes has a probability below one percent in a billion years based on some observation selection effects: if they occurred more often, we should find ourselves earlier in the timeline of our universe (Tegmark & Bostrom, 2005).

2. Big Rip. This risk could arise relatively soon, but not very soon: even in the case of very implausible values of dark energy, it is still 20 billion years from now.

3. Heat death is the most remote risk, and we have plenty of time to prepare for it.

## 5.2. Surviving the end of the universe and the multiversal Fermi paradox

If there is a way to escape our universe and to travel between universes, other civilizations from other universes would be also capable of reaching our world—but where are they? Typical explanations of the Fermi paradox do not work here, as multiverse (as much as we can guess anything about it) is almost infinite, exist almost forever, and thus the “rare Earth” or “universal extinction” hypotheses do not work here. This lack of the “interdimensional travellers” in the multiverse could be dubbed a *multiversal Fermi paradox,* more in(Turchin, 2018a).

# Conclusion

In this article, we provided an overview of several dozens of ways to overcome possible endings of the observable universe and the corresponding demise of our future civilization. Different ideas are applicable to different types of possible endings; however, these ideas can be categorized into seven main groups: surf the wave, go to a parallel world, prevent the end of the universe, survive the end of the universe, manipulate time, dissolve the problem, meta-level solutions.

The fact that we could identify so many ideas despite our early stage of understanding of the nature of the universe may be cause for cautious optimism about the possibility of such survival.

Moreover, if we will make irreversible pivotal acts soon, which will define the shape of our civilization, like starting space colonization by von Neumann Probes or defining goal system of superintelligent AI-Singleton, we should take into account the need to survive the end of the universe and insert it into the goal system of such AI.

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