

Consciousness and Time as Research Problems

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1 Introduction

This document serves to explain, to curious prospective graduate students and collaborators, why a professor trained in computer science might want to tackle consciousness and time as research problems. I am seeking students interested in pursuing these problems.

In the first part of this document I consider the problem of consciousness. Consciousness is primal to our human experience, central to most notions of morality, and currently inadequately explained; on a personal level I find it fascinating. In the second part of this document I argue that allowing for the continued experience of consciousness over time is a “most important” problem in a technical sense akin to NP-completeness: solving it would allow us to solve all but finitely many other problems. In the final part of this document I consider common potential responses.

2 Consciousness

“It is undeniable that some organisms are subjects of experience. But the question of how it is that these systems are subjects of experience is perplexing. Why is it that when our cognitive systems engage in visual and auditory information-processing, we have visual or auditory experience: the quality of deep blue, the sensation of middle C? How can we explain why there is something it is like to entertain a mental image, or to experience an emotion? It is widely agreed that experience arises from a physical basis, but we have no good explanation of why and how it so arises. Why should physical processing give rise to a rich inner life at all? It seems objectively unreasonable that it should, and yet it does.” — David Chalmers, *Facing Up to the Problem of Consciousness*

The phenomenon of consciousness is of particular interest to me because (1) it is irrefutably present in our lives; (2) it is central to our notions of meaning, morality, and choice; (3) it has not been adequately explained; and (4) it is amenable to experimentation.

Other standard “big questions” tend to lack at least one of those properties. The nature of dark matter (not central to everyday lives), why there is something instead of nothing (not testable), and world hunger (is in some sense adequately explained) are all in various ways compelling, but, to me, comparatively lack a combination of being fundamental, relevant, unexplained, and workable.

2.1 Primacy of Consciousness

Much like free will, consciousness enjoys a primacy in our everyday experience: we all have irrefutable subjective evidence that we are conscious. Unlike free will, which may well be illusory, consciousness is not so easily dismissed: if consciousness is a delusion, who or what is being fooled? By contrast, I am less concerned with whether or not we actually have free will: we certainly act and have the subjective experience that we do (e.g., we appear to be making decisions). Indeed, and more importantly, we have subjective experiences at all.

2.2 Consciousness and Morality

In my opinion, consciousness is critical to much or all of conventional ethics. It is central to our notion of “personhood” or “agency”, as well as notions like “harm”. Even concise ethical guidelines, like “as long as it harms no one else, do as you will” essentially reduce to the issue of defining harm and defining who you and the other “people” are. In my experience, most of these explanations involve, either explicitly or implicitly, some notion of consciousness. For example, we typically think nothing of putting out a fire, breaking a rock or cutting the grass — those actions may “harm” the recipients, in some sense, but the recipients do not enjoy moral standing — but would view cutting down other humans in a different light. This difference is sometimes initially explained via reference to life, but in practice the grass is definitely alive and we do not accord it moral weight. By contrast, our comfort or unease with the factory farming of animals, killing a dog to save a human, etc., tend to hinge on our judgment of whether or not something is conscious (and thus, for example, capable of the subjective experience of suffering), not merely whether or not it is alive. To see this in the extreme, note that an everyday definition of torture is the subjective passage of time without control over your own experiences (e.g., confined in a small space with a feeling of discomfort) — if you can render yourself unconscious, the situation is no longer as directly torturous. Murder, in many cases the ultimate harm, denies the ability to ever experience consciousness in the future. Dually, suppose you were to receive a splendid backrub while entirely asleep: it would in some sense not qualify as pleasant until and unless you were to awaken later to observe aftereffects (e.g., feeling relaxed and limber in the morning, being aware that someone had done it to you, etc.). Consciousness is critical to our notions of personhood, agency, harm, and thus traditional morality.

2.3 Consciousness Inadequately Explained

Despite these features, I find the current explanations of consciousness entirely unsatisfactory. From Aristotle to Locke to Nagel to Searle to Dennett to Chalmers, there has been a long history of work on the subject. For me, one of the more direct conflicts is that we all have subjective evidence of the existence of consciousness, but consciousness seems entirely unnecessary. That is, it is very easy to imagine a world in which we are all philosophical zombies, reacting exactly the same way we do now but lacking conscious experience or qualia. Consciousness is not evidently necessary — and yet we clearly have it. I find Dennett’s arguments against the usefulness of qualia as a component of subjective experience to be either unconvincing or irrelevant: it seems very clear to me that we have them, so dancing around the issue is not compelling. In the phrasing of Chalmers, I am much more concerned with the hard problem of consciousness (i.e., why does the feeling of subjective experience exist at all), but have no reason to believe his dualist stance (i.e., why should there be anything more than the physical?). In a similar light, I am to some degree fine with the deflationary rebuttals of Dennett and others (i.e., suggesting that there is no hard problem, just a series of natural phenomena). I am ultimately not interested in “why consciousness?” (cf. “why gravity?” — I am satisfied with “because it is reproducible” and thus use “why” as a shorthand for “what is the mechanism and how can we control and model it”) because the goal of science, in one critical sense, is to allow us to predict the results of actions in the world.

In this light, I find unsatisfactory all of the current explanations of consciousness of which I am aware. Epiphenomenalism is reasonable in the small details (e.g., while fear seems to make the heart beat faster, epiphenomenalism holds that the state of the nervous system causes it to beat faster) but ultimately does not address the issue of conscious experience (i.e., why do we have it or what is the mechanism). I am wary of dualism or soul-based answers for multiple reasons: both because there is no evidence to believe such a claim (or, more formally, it is unfalsifiable) but also because it is not clear how dualism is supposed to work consistently (it is not clear how the purely mental or transcendent part receives input from the world, directs the action of the body in the world, and also somehow simultaneously exists independently of the world). More recent mathematical approaches, like the now-popular Integrated Information Theory, may be on the right track but diverge wildly from our intuitions as currently phrased (e.g., simple mechanical devices or computer programs can end up with arbitrarily predicted high consciousness, as Aaronson and others point out). In addition, I am wary of any law or predictive model that requires you to define a “system” and gives non-intuitive or non-compositional results for the parts. I am fine with Chalmers’ conjecture that consciousness may be fundamental (in the same way that gravity is fundamental) with laws and interactions governing it, but to the best of my knowledge no satisfactory explanation, model or law is proposed.

2.4 Consciousness Admits Experimentation

As fundamental as consciousness may seem, we all have direct evidence that it is inherently linked to the physical world. This is observable locally from something as simple as sleep, but also appears in the scientific and medical literature in the series of studies and articles on traumatic brain injury. Lesions or brain injuries reproducibly relate to loss of consciousness, alternation of consciousness, post-traumatic amnesia, etc. Magnetic resonance imaging studies have found a positive correlation between the depth of brain lesions and the degree and duration of impaired consciousness, for example. In addition to such natural experiments, techniques such as transcranial magnetic stimulation (which uses a magnetic field to induce a small electric current in the brain) or transcranial direct current stimulation make it possible to expand our understanding of the cortical substrates underlying behavior. To some degree, when Dennett and others suggest that the hard problem of consciousness will be solved in the process of repeatedly solving the (not-actually-easy) easy problems, this is what is meant. Modulo the ethics, feasibility and ease (e.g., of doing double-blind setups) of conducting such experiments on humans, this is an area where it is possible to make progress, and where new measurement and experiment techniques are being invented relatively rapidly.

2.5 Understanding Consciousness

The four components of an interesting problem used in this section were subjectively or arbitrarily chosen. To me, consciousness (i.e., by what mechanism is there a subjective component to experience?) is the most interesting of the “fundamental problems” to pursue. It is present in our lives (like almost nothing else — indeed, it is in some sense so obvious that we overlook it), is central to our notions of meaning and morality (and thus understanding it is very likely to have both ethical and pragmatic benefits), had not been explained, and admits testing (with “now” as a much better time to be working on it than “one hundred years ago”).

Despite this, I do not actually believe understanding the mechanism of consciousness to be a “most important” problem directly or objectively, especially when compared to the related problem of sustaining the experience of consciousness over time.

3 Experiencing Consciousness Over Time

The Feynman Algorithm, according to Murray Gell-Mann:

1. Write down the problem.
2. Think real hard.
3. Write down the solution.

Deciding how to solve a problem — or even deciding which one to tackle next — takes time. To my students, I sometimes describe the practice of everyday science as the repeated implementation and evaluation of creativity in the face of failure, predicated on the belief that the universe is governed by discoverable, reproducible laws.

The Feynman algorithm above is a simplified model of general problem solving, and it is worth noting explicitly that Step 2 (“Think real hard”) requires energy (to carry out the computation), matter and spatial extent (to store the information) and the experience of consciousness over time. While the physics details are elided for clarity (e.g., a formulation with massenergy and spacetime is fine as well), if we want to be there to observe or take advantage of the answer (as opposed to, say, creating a world in which the answer is eventually displayed on a computer screen but we are not around to see it) we require that our experience of consciousness extend over time. As in the previous section, this subjective experience is central to our notion of personhood or agency. These basic properties (i.e., energy, space, and consciousness over time) are, in a fundamental sense, limiting reagents in this process. Of them, the experience of consciousness over time is currently the most limiting from an individual standpoint.

In computational complexity, if a problem X is “NP-Hard” then finding a practical solution to X also yields a practical solution to all other NP problems. In a similar sense, solving the problem of our time-limited experience of consciousness is “Hard” or “most important” in the sense that a solution to it admits solutions to all but finitely many other problems (modulo limits on the amount of matter available, etc.). In this section I lay out the core of this argument objectively, decorated with subjective details.

3.1 Time and Importance

“Ars longa, vita brevis.” — Hippocrates

While this emphasis on matter, energy space and time may initially seem abstract, when viewed from another perspective it falls out naturally. For example, humans create wealth (or its perception) over time by reorganizing matter spatially using energy from the sun or the earth. In the limit, essentially every human activity (from farming to baking to sailing, etc.) fits this description. The ability to produce and consume over time is the basis of economies and human interaction. From an individual perspective, the ability to experience consciousness over time is exhausted far before we run out of matter, energy or space.

A “most important” research agenda is thus to extend the extent of the subjective experience of consciousness. It is “most important” in the sense that experiencing a solution to it would allow you to experience a solution to all but finitely many other problems. Thus, in an expectation maximization sense, if there is a hope of success, that agenda should be pursued (regardless of one’s other goals, modulo non-standard cases).

3.2 What Should One Do?

“Reason is a biological product — a tool whose power is inherently and substantially restricted. It has improved how we do things; it has not changed why we do things. Reason has generated knowledge enabling us to fly around the world in less than two days. Yet we still travel for the same purposes that drove our ancient ancestors — commerce, conquest, religion, romance, curiosity, or escape from overcrowding, poverty, and persecution. To deny that reason has a role in setting our goals seems, at first, rather odd. A personal decision to go on a diet or take more exercise appears to be based upon reason. The same might be said for a government decision to raise taxes or sign a trade treaty. But reason is only contributing to the ‘how’ portion of these decisions; the more fundamental ‘why’ element, for all of these examples, is driven by instinctive self-preservation, emotional needs, and cultural attitudes. We are usually reluctant to admit the extent to which these forces govern our behavior, and accordingly we often recruit reason to explain and justify our actions.” — Donald B. Calne, *Within Reason: Rationality and Human Behavior*

Normative ethics, even at a subjective level, is a complex and contested subject. For simplicity, consider a concise secular model in which one desires to maximize the area under the curve for a utility function over time. While the exact formulation of this utility function is rarely specified precisely and humans are rarely as rational as one might imagine for modeling, this captures common-reported choices: do the most good over your lifetime or experience the most pleasure, etc. In this discussion we leave the utility function largely abstract so as to draw conclusions that apply across classes of such functions. We observably do not currently live in the best of all possible worlds, so there is at least one thing (and, more likely, many) that each of us would like to do or change.

Viewed through one lens, the main power of science is that it allows us to predict the future — to model the state of the world after we take certain actions. We can thus enumerate candidate choices, evaluate them, and then carry out one that is predicted to turn out favorably.

In computer science, we typically frame favorable outcomes in terms of “impact”. Undergraduate and graduate students often struggle to articulate what they want to accomplish with their lives or what makes good work. Some want to advance human knowledge (as in Newton or Curie), some want to make people happy (e.g., being an entertainer or artist), some want to build a structure that people will use (e.g., building a bridge or a computer program), some want to train or improve those around them (as in education or counseling), and some want to save lives more directly (as in Borlaug or Salk). Upon inspection, almost all of these notions of impact reduce to improving or extending the life experience of one or more humans — increasing the area under the curve, as

it were. Indeed, while reducing the human experience to numbers can be uncomfortable, groups like the World Health Organization or the United Nations increasingly use metrics like “disability-adjusted life years” (an extended notion of “person-seconds” that accounts for quality of life) to compare potential charities, interventions or activities. If one activity can keep ten people alive for one more year each and another can keep two people alive for five years each, they are in some sense comparable.

For the purposes of this discussion we call a utility function “non-standard” if it has certain discontinuous or asymptotic behavior, or if at some point it becomes and remains non-positive. For example, a utility function in which you are infinitely happy if you possess one thousand tomatoes tomorrow but otherwise have a happiness of zero is non-standard. Non-standard utility functions are rare in secular systems of ethics (e.g., as time goes by you can imagine learning more, discovering more, helping others more, experiencing more, etc.) but do occur in some theistic systems.

For standard utility functions, all other things being equal, a scenario in which the problem of experiencing consciousness over time is solved dominates all scenarios in which it is not. This can be seen mathematically, but also follows intuitively. Imagine that you have ten or more one-day activities you would like to do, but only five days available. A scenario in which you can spend three of those days to give yourself eight or more additional days is better than any allocation of the original five days to activities. (Recall that we are not considering non-standard schemes with infinite-value activities.)

3.3 Expectation

In this formulation, given a standard utility function, if it is (or will be) actually possible to make substantive progress on the problem of experiencing consciousness over time such that you can spend X of your conscious time to gain $Y > X$ additional conscious time, doing so is almost certainly an optimal choice. While this is possible in short term, trivial fashions (e.g., spending one hour eating yields more than one hour of consciousness compared to a world in which you stop eating entirely), the research question is whether it is repeatedly, significantly or sustainably possible in a way not currently realized.

If the answer is no, this research agenda should not be pursued. Currently, the answer is not known. If we are pure expectation-maximizers (and humans manifestly are not), then this agenda is worth pursuing until one is certain that the answer is no because the unbounded future value obtained upon success, multiplied by even a small chance of success, can exceed any other finite value. Indeed, to a second order, investigating whether to not it seems feasible or could be possible is an optimal use of time given current uncertainty and potential benefits.

Thus, either pursuing this research agenda or investigating its feasibility is optimal for standard moral systems.

3.4 Past and Present

A common consideration for a research agenda is “why now?”. In the past, with more limited technology, there was no reasonable hope of significantly or sustainably extending the subjective experience of consciousness. In such a setting, seeking after such an extension would be both a waste of time and a source of eventual disappointment. As a result, social norms favored those who accepted starkly limited time — just as they favored the acceptance of slavery, hunger, gender-based subjugation, slow travel, etc., as unalterable facts of life. If one has no hope of making any forward progress toward air travel in one’s lifetime, it is likely not fruitful to rail against one’s inability to fly.

Indeed, once-insurmountable problems become so accepted after they are solved that it can be hard to remember that there was credible opposition. Malthusian catastrophes have been legitimately considered in areas from agriculture in the 18th century to oil production in the 20th. I am not saying we will never run out of oil, but I am saying that then-legitimate concerns that, for example, US crude oil production would only ever decline starting in the 1980’s did not come to pass (cf. new detection and extraction technologies). Similarly, I am not saying that it is impossible to have so many humans that it would be difficult to feed everyone, but I am saying that concerns about food security in India and Pakistan in the 1960’s and 1970’s did not come to pass (cf. new high-yield, disease-resistant wheat varieties).

I believe that there is an appreciable difference between this century and a few centuries ago in terms of potential for scientific and technological progress: the computer. The fundamental difference is that all other pieces of technology multiply our physical force (e.g., the lever and combustion engine allow us to move bigger rocks than we could otherwise, etc.) — the computer is the only device that multiplies our mental capacity. In this light it is unsurprising that computers have become the “language of science”, with modern efforts in areas from drug design to airplane wing creation being dependent on computers. From computing power to oil exploration to infant mortality to the Green revolution to astronomy, we are in an apparently-unending golden age. For example, in *Science’s Endless Golden Age*, Neil deGrasse Tyson notes, “remarkably, this golden age applies not just to our understanding of the universe but to nearly all scientific discovery . . . astrophysics doubles every 15 years and Moore’s law doubles computing capability every 18 months.”

I once had the chance to eat lunch with Tony Hoare. Hoare was born before the first general purpose digital computer and was personally involved in a number of fundamental advances in computer science. The improvements observed over the last one hundred years in computer science are simply not found in most other fields at other times (e.g., ground transportation in the seventeenth century has nothing akin to Moore’s Law or the improvements in computing technology in the last one hundred years). While it is the hubris of every age to proclaim its exceptionalism in one way or another, I believe the rise of the computer makes such claims more true than false when speaking of modern technology.

I have no evidence to believe that this research problem is impossible, much evidence to believe that things are different now than a few hundred years ago, and a standard ethical system. My value of a world with a successful resolution to this problem can dominate my value of a world without it. As a result, investigating the feasibility of this research problem, and then pursuing it directly until it appears infeasible, is an optimal move.

3.5 Directions

“I have never been particularly fascinated by aging. I have always simply understood that it is obviously the world’s worst problem.”
— Aubrey de Grey

A number of potential approaches have been discussed for experiencing consciousness over a greater time, from those that focus on medicine or aging (e.g., telomeres, cancer, mitochondria generating free radicals, etc.) to those that focus on non-biological consciousness to those that are more speculative (e.g., speeding up the perception of consciousness so that we experience more of it given the same amount of time, dramatically increasing the speed and ability of computers and other decision-making aids). This agenda does not advocate choosing one a priori (e.g., drop everything and study telomeres) but instead surveying fields and investigating feasibility. For example, one might investigate the hypothesis that it is reasonable to think that technology will advance to the point where consciousness continues over time within the next forty years (e.g., via anti-agapics, non-biological consciousness, etc.).

It may be that one can approach this research problem via existing expertise in computer science. It may be that the expertise associated with, for example, a medical degree would be more relevant. It may also be that the most efficient way for a computer science research group to advance this agenda would be to provide financial support for another group (cf. high-income people spending time volunteering for charity vs. spending that time earning money and giving the money to charity).

4 Concerns

“Suppose you find an unconscious six-year-old girl lying on the train tracks of an active railroad. What, morally speaking, ought you to do in this situation? Would it be better to leave her there to get run over, or to try to save her? How about if a 45-year-old man has a debilitating but nonfatal illness that will severely reduce his quality of life — is it better to cure him, or not cure him?

Oh, and by the way: This is not a trick question.

I answer that I would save them if I had the power to do so — both the six-year-old on the train tracks, and the sick 45-year-old. The obvious answer isn’t *always* the best choice, but sometimes it *is*.” — Eliezer Yudkowsky

In this section I consider a number of common concerns and questions that one might associate with a research program of extending the subjective experience of consciousness.

What if you would actually make better progress on X by focusing on Y and discovering something by happy accident? This concern is mentioned only because a surprisingly high number of initial reactions are ultimately equivalent to it. First, note that this concern is not about the research goal, just about the best way to get there. Second, unless one has specific evidence that working on X is more likely to yield happy accidents, this does not help one choose X over X' . To put it another way, if working on chemistry measurably resulted in more spontaneous computer science discoveries than just working with computers, rational computer scientists would start purchasing test tubes.

Brevity gives life meaning. Does it? Or are we tempted to think that because entertaining the opposite claim has historically been quite depressing? The sunk cost fallacy is quite relevant here: the more we have comforted ourselves in the face of loss with such platitudes, the harder it may be to set them aside and make progress, because it would mean acknowledging that we were wrong before. More formally, an ethical system that truly holds this premise would be “non-standard” in the terminology of this work, and thus does not admit the expectation argument presented here. If you have such a moral system, seeking to extend the extent of consciousness is unlikely to be an optimal choice for you.

Alternately, consider whether or not you want to live to see tomorrow — to live one day more. Similarly, consider whether tomorrow you might want to live one subsequent day as well. What reason do you have to believe that that inductive step will change in the short term?

To put it a third way, perhaps brevity does give life meaning, but perhaps brevity is 800 years (for example) rather than 80. A thousand years ago, sixty years would be characterized as a long, full life by some settings (e.g., Lancaster’s data on members of the English aristocracy). As a thought experiment, consider whether someone who is over sixty now would have preferred to have died at sixty (e.g., to give life more meaning through brevity). As technology increases and longer lifespans become more common, our cultural definition of a reasonable lifespan shifts. But the notion is just that: cultural — not inherent.

Solving this research problem will not help us solve certain classes of other problems. This is true, but those other problems were not approachable anyway. Suppose we divide problems into those where it is possible to make useful progress in a finite amount of time and those where it is not. For problems in the first category, a greater experience of consciousness over time is helpful. For problems in the second category, it is not helpful, but problems in the second category also cannot be meaningfully addressed in the current case of starkly limited time.

One should not take actions out of fear of death. This concern is difficult to address because it is rarely articulated beyond this starting point. One reply would be to consider whether or not one wears a seat belt or visits the doctor. In the limit, seeking to extend the amount of time for which one is conscious is not appreciably different from those activities. It is worth making a distinction between an irrational fear and a cost-benefit analysis. While it may not be rational to fear death per se (e.g., unless you have reason to believe you will experience something after it) — as opposed to, say, fearing pain — it is still typically viewed as reasonable to take actions that extend one’s life (as in the seat belt example above). What is the difference between engineering the systems on a submarine for a safe and long undersea voyage and engineering the systems on the human body for a safe and long overland respite?

This line of research is overshadowed by the possibility of certain types of catastrophes. Unless we have particular evidence to believe that such an event (e.g., a meteor strike) will occur shortly (i.e., before this research program is finished), this reduces to one of two previously considered issues. Either the meteor strike is unsolvable, at which point we are lost regardless, or the meteor strike can be averted given finite time, at which point experiencing its solution is more likely if we have more time to solve it. To put it another way, a hypothetical meteor strike imposes a non-standard utility function (cf. “if you don’t have 10,000 tomatoes by tomorrow” vs. “if you don’t have a meteor shield by tomorrow”) and the question reduces to one of math and expected probabilities (e.g., how far away “tomorrow” is in the example, among other considerations). Personally, I have no evidence to believe a preventable mass catastrophe for humans is likely in the time frame considered here (e.g., the next 40 years).

Allowing more people to live longer would create many problems (e.g., overcrowding). The reasoning and logic behind this concern are so problematic that it is difficult to address, but it is included because it is so commonly raised. Notably, unless one is very careful, this concern is isomorphic to “the world would be better off with fewer people in it”, which has dangerous implications. I will avoid that reply (although personally I find it fairly ironclad dismissal of this concern) and instead point to the lessons of history. While there are finite resources on earth, this sort of Malthusian catastrophe has been predicted multiple times before and has not come to pass, and I do not see any additional evidence raised in the modern context that changes the established conclusion. To address the concrete concern most commonly raised, data currently available actually link increasing wealth and lifespan to a decrease in fertility. Finally, any such future problems that arise from having more time are ones that we would have more time to deal with.

Some will not want to experience consciousness longer. I am not proposing anything mandatory. You can, now as in the past as in the future,

always choose to stop. As above, history and cultural anthropology suggest to me that in one hundred years (for example) we will look back on the moral strictures of the present day in the same way that we now look back on many of the moral strictures of the past.

If you succeed, the benefits would only reach the elite. First, that is not necessarily a reason not to pursue something (e.g., if I publish a book of poetry, since a significant fraction of the world’s population lives on less than a dollar a day, those poems are necessarily only brightening the lives of the “elite”, and we are fine with such poets). More importantly, however, historically that has not been the case. From the refrigerator to the television to the car to the cellphone, devices that were originally found only in the hands of the wealthy are now ubiquitous. This can be seen in developed countries (e.g., possibly-manufactured outrage about news reports showing US welfare recipients with cellphones and refrigerators) and in developing ones (e.g., where cellphones are increasingly used for everything from monetary transactions to clinical health care). In addition, having more time gives us more time to fight for social justice and equality (cf. the suffrage and civil rights movements in the United States).

5 Conclusion

In my opinion, there is one interesting problem and one “most important” problem (in the sense that solving it first is provably optimal under common assumptions). The former is the problem of understanding why (i.e., by what mechanism) we have the subjective experience of consciousness sufficiently to predict and model the world we observe and explain our direct experiences. The latter is the problem of expanding the extent of the subjective experience of consciousness — allowing us to experience it exactly and only long as we desire to. Until the latter has been ruled out as effectively impossible in the given time frame, investigating its feasibility and ultimately pursuing it are optimal choices.

I am interested in working with graduate students, postdocs and other research collaborators to tackle these problems. If you are such a person, do not hesitate to contact me.

This is version 2 of this document. The version number is likely unimportant, but every time I release something without a version system it comes back to haunt me.