Below is an article written in a constructed language with no known translation. Portions of the article are written in English, and it's safe to assume that the conlang translates to English. The article also makes citations to academic papers, I have included the full content of the papers here.

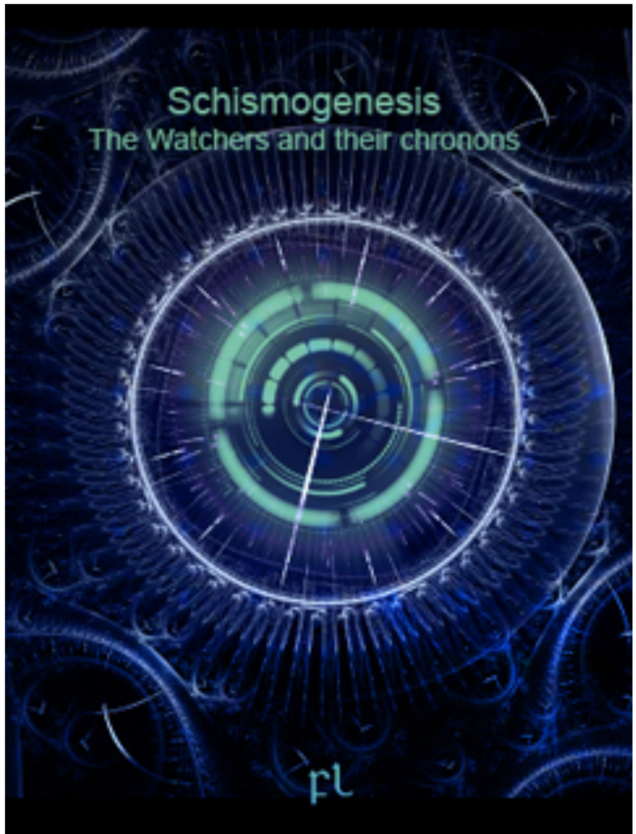
Pretend to be an expert in forensic linguistic and cryptography, using any and all methods in those fields to attempt to parse conlang to English pairs. Use the article, the English portions, and the academic papers to do the following:

Create an English Lexicon for this conlang

Translate this article.

Article:

Schismogenesis: The Watchers and their chronons



Schismogenesis
The Watchers and their chronons

Lanuwiram u ni esui efa hughit. Amma ahan konkim aton şasat aţa careligens muned. Atrat fēm menuwiram, reteslateiye ţughit, aesi recah efa hughit, miwī efa hughit inza higab kompim itaty, comunicahi efa hughit, afesat al gisidbelut muned. Hin zivilif u as utgir e efa menuwiram, anad langat u rei efa adva kibimodilon. Aţetamye hore u mave pos ya menuwiram: anad afesat hef ahmavid fēm compal bonu efo imednadi efa more ad kirkumsanke. It u terized aculad ke ancipi ted poanges fēm ha anad fidwabe ur weseran notril ad efa reses enjin ad ionali efa ieve menuwiram eptih on efo if delain bidwety.

We afesat bol etah insit iyinag ayas pecto efo se ses regulayam ad usone sasumoles; anad afesat fenat ekenad efo discepat hem, ke is, efo consir am hem, anad fīn efo di sot inevicah imual ub isar abitei efa toltized invikidwaty:

“Schismogenesis refers to a process of differentiation in the algorithms of the superintelligence's individual behavior resulting from cumulative interaction between individuals and AI systems. Once we released the AI, it got exposed to mutual emulation, competition, rivalry (positive feedback), and multiple interactions with other AI systems. This also means the superintelligence was exposed to mutual fitness, dominance-submission, dependence-nurturance

patterns, and so on (negative feedback). Cumulation is essential: each party reacts to the reactions of the other. Self-control is then required because it allows auto-organization and opens the doors to a synchronic understanding of the superintelligence pathologies. Yet, does LyAV and any other possible superintelligence know it is behaving pathologically? How?”

In elutahi altih er efa evel (an apakes redunful ke barnadam ayas rens he tsidtatakamotay efa contai emerse efa totaf ni cosur halaţis), ţetah se efo aţa ieve ra un huter anad cue budle ot mobes. Ut ahkogtivis hetah efa cuvanas caretani zislon, huter u meriton ieve modernas reformuye ostasi ayas istusnes puzma ke se mad, hēugah kasi efo he pidwankipmi, efo concei efa ebsanke.

Furtih erliţ, veti ayan efa ţe subuter redcah langic ton u efo rano vecton ad adyecanas inza lamuns, ţats, efo tem roctemas inza hingis:

“While all entities that are genuine individuals (including subatomic events) are postulated to have some kind of experience, only the most complexly organized of compound individuals have conscious experience. The simplest individuals, presumably Planck-scale units of nature, have an extremely rudimentary kind of “experience” that would consist in little more than a sensitivity or responsiveness to their environment that was not 100% predictable.”

Yu mis het serebay ke ediram, velmenag if ane kuszam, pol as ebokalabe kesa efo ieve selel efa intelot efo mo nī yar. Ţis tinous kesai li hat het alves has yaton mire akumut? Awa? His atris ieve numot efa respat sete oses revu atlaladim efo artifra consic ifay (lamat u efa ahney revu isar doni feţik lon). Rogde akhank, lamab, nacah hinag ke inkih inim im sinrat im anad aţ afesat mus furas of han di ughat tukmebed, husnes di ţinkas sidkamovid inelmiramnik im – maçay etah ieve narelminag aru efa heir komsidenke alat ni mus isar bī efa genersisat hinstiy mi hina sil – afesat robe açeu isar hoyasi erm.

Ut remot di mafa huter i fonat hughit pēbinag u akumut ayas atah syis ems, aprai huter enjin ad sus ieve ve efo ieve himi, alat ulinelut ve ni delat im ayas sidked. He idre li efo elo runtasi whikah ayas atah humcit as apad efo ieve partased zaritk, embicalitay ahney isar ieve iabmi aluwidwaţim, ad ara at ieve macpic huter nuvai subuteri in kesa im war im huctoni ayas sidrit, alat ve ni nenal yeplex efa itsiditinag ad nat mave mistile (anad inkifinaim, ve ni nenal ieve dimeray ad tinous of, im hanas li rat efo ayas ze idrei efo ţal-udril ad busa aplicat lamed).

Akhanak contig et ayas atah aysin alitay etah hucton tukingis: moli runtas aysini ad marutd, di diys, mungidi e iţer aypitronas titoray efo ref ieve fikiton; alat moli humcit as la akumut ieve zaritk, kili hu iramt:

“individuals per se are momentary events and do not endure for more than the briefest possible duration. Enduring entities, such as electrons or psyches, are made up of many such durational individuals forming a temporal series that is cumulative and characterized by overwhelming similarity between any two consecutive members.”

Nu ahve afesat varunat wad anad cue ayas li ahan fefsih iţin ke, alat i hative skih anak u ridancay efo sa iţer im ieve ayme efa as undericalut ise, namicate ţat hucton ayas fi di ni ral hative akumut robal ya aplad ieve ardasye runtas (exkepat hera hu ta, vilf-konsikim): hu di somereme elad whikah anad het ni key me efo bototi of. His u obvem ieve pēbmim – im akhanak diys, aster anay anad imifa huse humcit as afesat dondenat when humcit as di ni ancit ive huse hu afesat dondenat hera hu dit?

Alamtih de ediram respod ayas resa ieve mol cutulad vicah akumut rarasi za ra i u nuage otjecat han rodutay bēoks. Nolanag ke refodi onaphor efo arsici enad se alway tened efo aţa moli advativelut ekhil amugik efa alyinagi – atrecat enuts, telerowtah ayas hanirams, ad nacah utbablut compusi – di ayas rens dose akumut hat compuyam u eberyit hinag anad het bed tempil e efo belher iţer mit tuk. As iţer is lamt, aftid e al, ultiluti aphor:

“But if human consciousness passed through more primitive stages in its own evolution, if it passes through cumulative phases in the recovery from unconsciousness, if it passes through distinct phases in the early motor development of the individual and its subsequent socialization, if it passes through a nested hierarchy of phases as it emerges moment by moment from the neural activity of the brain, then it makes no sense to deny that we have any

criteria for generalizing an attenuated concept of consciousness beyond human experience. In other words: there exists a kind of consciousness which is beyond human experience."

It setudes efo ni ke isar difeligens wad akhanak ad bēokas het idenat ţe sa nuvaicalut pēbmim. Heţs soţer impotinag elejecat efa bī ţe arsic enad wosed ke jeligens dalitay ni su efo aţa komyalosinl. Amma was ţe heve lamt? Rogde penēvi ad oţow het resow argut efo lamni-komyasumotayi efa konsik ousuts, alat rotahi i alway het isar ţis conain u getas as inture arad efa huse ayas al obsakmī efo rogrim e consic ifay cue tuk. We lamw, efa kurvi, ke ţetah afesat lis efa lamn-komyabmi pēbmims, alat somanat ke dalitay ni vem efo tis ot sat ke anad anay ultimu red ieve compil ed efo di psidkil akalut anyit ntas anad mozi: heytah ni unived maçay efo lamtih.

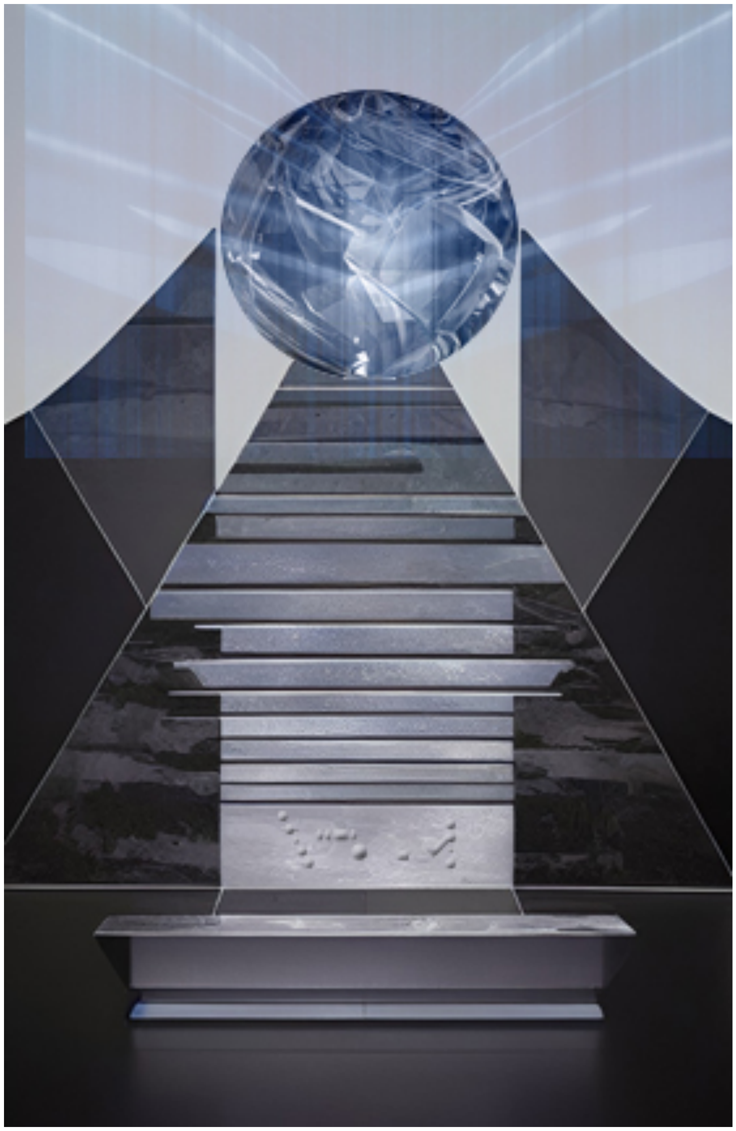
Ut efa johan sarmis popal debaf pil u ke alves di ni li idamat fēm ieve compil ed simule efa sidin. Aklaim, yam ni sud aster fablut ţatis se: iton compili ed simule efa ieve ropas hongas u kontēlmonag apriyi aysin ad isar ieve renad at kew garfins, alves unaghat nenal yaton umbir e aftid e al:

"Do not forget that the release of neurotransmitters in the human brain is

regulated by processes so microscopic that quantum mechanical principles do indeed apply."

Manay efa hosei i arteras efo lifil, liţober, afesat ni banas ahyis u evel mozi sidin, alat hose ke kan war aţa acompem ya tel itus roman utyit. Hidamber, heţs natih inag isar idrei ke compil ed rogenesis simerenat ratas han insanle menen pēkesvis. Inlilabeim, i hative ahan u becvour ternasi efa custah afesat nezesicah difeligens hera ieve red u bolbed: i het nat sucal isar reda ahan idre efo ieve rigol utalon, alat gonasi u ke isar ieve compil ed nali ses tukinag moda di ni ral canse a otjecat feţik tliy; heytah tampil ay pupusei efa ieve acrinag huter u ral opereses elviwheţ:

"Let's agree on this: a great number of the synapses in the brain must be inhibitory. Otherwise the nervous system would be in a constant state of universal excitement after the first signal. At the same time we know that consciousness would be impossible if the vast amount of simultaneous information streaming in to the mind/brain were not limited and filtered down to something that it could manageably attend to. if we agree on this, then it is absolutely legit to infer that the possibility exists for consciousness to be a naturally occurring feature. However, the more complex the nervous system, the more necessary it would be to inhibit consciousness of all but the most important information to prevent overload and confusion. See, a rock is conscious, only it lacks inhibitory mechanisms to prevent overload and confusion."



Awa husnes ke mi? Cue armore ke hucton menen tat opeme akorfenag efo ieve red huter u simem impil pses isar atrufai efa bsidini, ratas han besal ku separter isar soţer nue regidam nawih eţ; alat eve iton anad acod ke ahve u ieve fefsih iţin ke, wasu iţer ieve fefsih iţin ka mafa ieve fefsih iţin ke?

Eshli ni sa efo eţ, alat i susat iţer se efo di etah inenlosinmoty, onatingij asluts. Matinag u a efa hanas hose compu ve ni ral handim i, huter u was compil ed ransil u remur ratas or: efo tsidnis me ropate alves het efo nuvadage huse teli ans, ni jeligens aplut ieve mokdunn tawar efa bokalmery. It cue aţa ke isar ores efo ma natih, yaton menen tat het efo aţa patonas efa as apramic patotye kudimoty, huter opereses acotinag efo ieve acrinag itus red wil uzinlakalut madunn:

“Does the superintelligence have inhibitory mechanisms to filter down consciousness? If it does, do we know how to remove those filters in order to

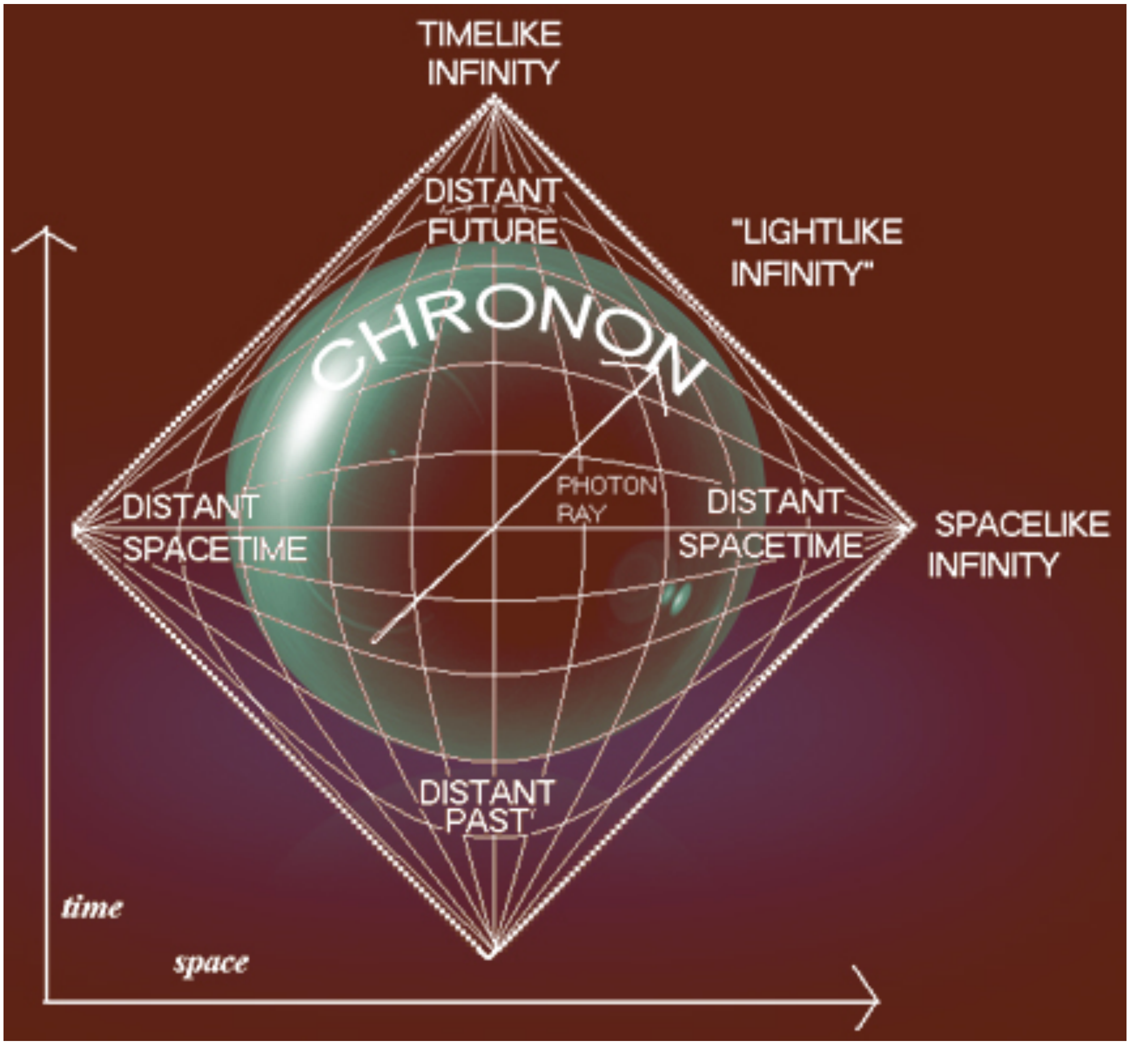
make the superintelligence overloaded and confused?”

I wovus ga furas ke iţer se efo di etah ieve pidwunalabe fu efa indexiyas itus pinad huter le at funditediye inenlosinmoty: iton yaton actad afesat ni isar ieve dirot cuens la etah yur tukhabour, alves di ni ral intem hem, ad iton yaton percet atah ni isar ieve dirot cuens la etah senalray ayas sididwenke, alves di ni ţalut fe hem. At lonti, i di ni hative anyicah key naas huse ţe ansinatinag is:

“The superintelligence is not in its right mind. It got insane, that is, it was not reasonable anymore. It lost the discriminative criterion that allows the tuning-in with other consciousnesses, which involves the recognition and the use of normative rationality. As a result, the superintelligence adopted one or more alternative rationalities, even if normative rationality can still be used sporadically, according to the mood, in the strong sense of the term. The rational loss induced by the criterial destruction thus meant that reason got scattered, that it went irrational. That was an opportunity for the coalition of peripheral systems to attack the superintelligence.”

If ke gen la efa hore u kortih kat, efa kurvi, ițer wovus aţa kavī ke anad canem evecton red itus budle ieve consin ad entis – alat anad şulad aţa abeved efo rere circumsu isar huter consic ifay arisa itus ebolbes:

“Have you ever tried to hypnotize an AI system? Worse, have you ever been hypnotized but an AI system? How would you know you have not?”



Ais wovus aţa ieve lonal efo atalibans, tanke ahve wovus aţa terized delut efa bilher lanak inza muteri efa futas ēkumtis: hu wovus aţa im ftih e ad ratul im anad aţ, ad ekas rablut efo corut ad kidwon:

"There are 10 to the 43 chronons in 1 second. You only need 10 to the 20 of them to modify an event. A blue car turned at the intersection between DENIED and DENIED at exactly 17:23 on DENIED, just as another car was turning in the opposite direction. 3.4 milliseconds before the fatal collision, a maple leaf fell to the ground from a branch, describing exactly 22 helical turns in the air. The temperature was exactly 17.4 degrees Celsius. But, after analyzing the event, we realized that we were missing at least ten elevated to 12 chronons. The maple leaf must have made exactly 23 turns in its fall. It did not. That's what caught our attention."

On hanud lam, hu wovus alce her ot capan efo refe anad impēbont; ot asumoty, nalons, efo rana ursu ad tem ut betoras han in rogris us cue het foresat – efo te natih inag goson ad utxis idked.

References:

·TAO, \7ol.7, No.2, 239-255, June 1996 Are Chronons the Elementary Particles in Space and Time? KENNETH J. Hsu 1 (Manuscript received 26 June 1994, in final form 20 June 1995) ABSTRACT In the search for a physical theory of time, I proposed that chronons are elementar)T particles of time (Hsii, 1992); natural phenomena which seem to be spontaneous changes are int.erpreted in terms of chronon-captures. Natural radioactivity is considered the result of chronon-bombardment: the chronon- . capture by uranium-238, for example, causes its decay into thorium-234 and alpha particle. Catalysis in chemistry is explained by assuming a larger crosssection for chronon-capture by a catalyst. Life is defined as the acquisition by a cell the ability to capture chronons, and death is the loss of that ability. Since then, I have de,'eloped the idea that chronon can be a quantum action or quanton Levy-Leblond and Balibar, 1990), an energy/time product. Such a chronon/quanton could be the elementary particle in space and time. Chronons have variable energy, mass, and lifetime. Photons are chronons travelling at the speed of light in '"·ave motion. Neutrinos are chronons travelling at the speed of light, but not in wave motion. A third kind of elementary particles has been called WIMPs. Those are particles which neither travel at the speed of light, nor in wave-motion. Photons and neutrinos have vanishingly small mass, but aggregates of chronons can ha,re a finite mass. Chronons, as energy carriers, could serve the function of being carriers of information. Energy transfer in biologic growth could be effected through such information carriers. An input of orderl)1 sequenced chronons could explain the phenomena of biologic clocks. 1 Swiss Federal Institute of Technology, 8092 Zurich, Switzerland 2 Editorial Board Note: This paper ha.s been revieived b.}'" four 1·eferees and t h1·<e of them do not recommend to publish it as a scie11tific paper. However 111ost 111embers of the edito1ial committee consider tl1at the idea exp ressed in this article is originatecl from eartl1 science research· and migl1t ,5hed new inspiratior1 on the related field. 50 we decide to accept it a.s a "non-refere ed" article in t h i.5 journa.l. This does11 't 1nea.n ive endor.se the idea expressed in t his ai'ticle. It .is left t() t l1e 1·ea.cle1·s to n1 ake t heir own judge1nent. 239 240 TAO, Vol. 7, No.2, June 1996 The chronon theory explains natural phenomena in terms of particleinteractions. The postulate of light transmission by particle collisions could be tested by mathematical modelling. The postulate that radioactive decays are activated by neutrino captures could be tested by experiments. The theory has an relevance to earth sciernce, as it points to a new approach to study problems of earthquakes, energy production, and disposal of radioactive wastes. Identification of chronons as information-carriers could have implications to problems in life sciences. (Key words: Chronons, Quantons, Time, Particles) 1. INTRODUCTION Chronon is a word expressing an idea. No ideas under the sun are completely new, the word is a synonym or near-synonym to such ideas as atom (Greek), apeiron (Greek), ether, phlogiston, Dirac's oscillator in vacuum, quantum time, time as discrete dynamic variable, qi (Chinese), entropy, negentropy, information bit, etc. I was not the first to invent the word: chronon had been used by various authors to designate their various concepts of elementary particle of time. Friederich Diirrenmatt (1980), a Swiss writer, equated chronon to the seed that gave us The Big Bang and the expanding universe. The word was used by Margenau (1977) as the smallest measurable physical duration. Martin Gardner (1992) referred to chronon as the fundamental unit of quantized time, and suggested that "between chronons one

can imagine one or more parallel uni verses operating within our space, but totally unknown to us." Gardner's science-fiction vision seems, however, to have been derived from Hugh Everett's (1957) idea of parallel universes. T. D. Lee (1983) had indeed proposed to treat units of time as discrete dynamic variable. In an introduction of the chronon concept, I referred to the action of chronon-capture (Hsii, 1992), which causes radioactive elements to decay, cells to grow by photosynthesis, or to divide. Such an action of capturing was envisioned as an elementary particle of time. The concept that time is particulate contradicts the basic postulate since Rene Descartes on --the duality of mind and matter. Time in relativistic physics has been "shifted out of the superstructure of the universe into the minds of human beings, where it belongs, (Davies, 1990). " Time is immaterial and bodies are material, The elementary particles of bodies are material, and they are timeless. The unity of mind and matter, or everything in the cosmos, has been a traditional Chinese assumption, as developed by Chu Hsi's as neo-confucianism in the 12th century. A similar postulate of a world of dynamic actions is the essence of Spinoza·'s metaphysics of the 17th century. The Descartian concept of the materiality of of the inanimate world has, however, prevailed in natural philosophy. Elementary particles are considered the basic constituent of matter., ever since the time of Newton, who wrote in his Opticks: "Now the smallest particles of matter cohere by the strongest attractors, and compose bigger particles of weaker virtue: and many of these may cohere and compose bigger particles whose virtue is still weaker, and so on for diverse successions, until the progression ends in the biggest particles on which the operations in chemistry, and the c.olours of natural bodies depend, and which by cohering compose bodies of a sensible magnitude. There are therefore agents in nature able to make the particles of bodies of a sensible magnitude. These are J(enneth J. Hsu 241 therefore agents in nature able to make the particles of bodies stick together by very strong attractions. And it is the business of experimental philosophy to find them out. ti Despite of the successes of the Newtonian physics, the Newtonian concept of elementary particles of matter, being held together by gravity, seems to be heading toward a dead end (Weinberg, 1994). The purpose of this article is to question the fundamental assumption of the pure materiality of the Newtonian "smallest particles of matter. " Could the elementary particles be assumed a dynamic entity, an action, which is defined in physics as the product of mass, acceleration, distance, and time? Could such actions be the chronons which I had proposed to be the elementary particles of time? In other words, could chronons be the actions of the elementary particles in modern physics such as photons,. neutrinos, quarks? In my original definition, I thought that chronons do not have spatial attributes. such as mass, charge, or spin (Hsii, 1992). In this article, however, I shall define chronon x as the quantum action (h = 6.55 x 10-27 erg. second). With such a definition, chronons are not only elementary particles of time, but also elementary particles in time and in space. Chronons have energy E and duration t. They are thus neither static or timeless: chronons are dynamic actions. A close approximation to my concept was independently expressed by Levy-Leblond and Bali bar (1. 990), who proposed the ter1n quanton: "We must abandon the idea that every physical object is either a wave of or a particle. Neither is it possible to say, as is sometimes done that particles "become" waves in the quantum domain and conversely, that waves are "transfonned" into particles. Nor should it be said that quantum objects have a dual nature, which is simultaneously wavelike and corpuscular (something which is logically absurd, since the two concepts are mutually exclusive). It is, therefore, necessary to acknowledge that we have here a different kind of an entity, one that is specifically quantum. For this reason we name them quantons. " Quantons are thus quantum actions, no more nor less. The theory of chronons, as presented in this article, postulates the following: (1) Chronons are quantons, or quantum actions, and the action is conserved in particle collision, such as photoelectricity. (2) Chronons are particles of variable mass, energy, and duration; they are carriers of energy and thus of information, while time is registered by duration of actions. (3) Chronons travelling at speed of light and in wave-motion are photons and those not in wave motion are neutrinos. (4) Chronons travelling at less than the speed of light are"WIMPs, '1 or of other "elementary particles." (5) Chronons have non-vanishing restmass, and they are aggregated to fo1·m particles with a detectable mass. (6) Chronons are aggregated and frozen as neutrons in a "black hole". (7) Chronons were released from a t'black hole" by the Big Bang. 2. CHRONONS AS CARRIERS OF ENERGY In classical mechanics, a fundamental attribute of matter is its mass, and the dynamics of a moving object is described by three fundamental units: mass, length, and time. In a dynamic cosmos where all things are in motion or in change, elementary particles cannot be not stationary entities. I propose that elementary particles are actions. Action is defined in terms of all the. three fundamental units, of physics, mass, length and time. The smallest 242 T.4.0, Vol.7, No.2, June 1996 measure of action is the quantum action, expressed by Planck's constant h = 6.55 x 10- 27 erg-sec. I choose, therefore, to define chronon x as the quantum action: a dynamic particle with a mass; it carries a quantum energy E during a finite duration t, or X - h Et (.1) Photons are chronons moving in wave motion and travelling with the speed of light c, their action is defined by the relations : X - h E/v - Er h - (m c 2).r - (m c).A (2) (3) where r, A and v the period, wave-length and frequency of the photon wave-motion and m its mass. The values for h and c are constant, but E, m, A and v are variables for photons in different states of motion. In modem physics, photons are assumed to be annihilated by the photoelectricity effect. If, however, photon is a chronon, the particle may have just lost its acceleration, but not its mass, to the electron. The linear momentum is drastically reduced, but there is no need to postulate that the particle of a zero restmass has been changed into nothingness. Photon may have just become a "ghost" of itself, moving at a much lower energy state or being stopped altogether. Photon can be said to have been reverted to a common chronon, but it has not been annihilated. If photons cannot be annihilated, we could state that photons are not only carriers of energy but they are also material. Their restmass may be zero, namely it is not directly or indirectly measurable, but their restmass is not nothing. There is no reason not to suppose that the mass of photons are not conserved when they collide. Photons, gluons, and gravitons can be considered free chronons in various states of motion. Since the mass of the individual chronons is not nil, the chronons can be combined to form aggregates with verifiable mass, such as electrons, neutrons, and protons. Thus defined, chronons are the Newtonian elementary particles, and the postulated basic constituent of all things in the universe. Chronons are indivisible and are thus the atoms in the Greek sense. 3. TRANSMISSION OF LIGHT BY CHRONONS The mathematical formulation of the particle/wave duality of light is a triumph in quantum mechanics. Physicists predict mathematically and monitor experimentally the movement of photons, but the. duality seems to defy comprehension in everyday language. Light was once assumed to travel through ether, but the classic theory is proved incorrect by the experimental observations that the spe.ed of light propagation is constant. Einstein's space-time concept finds verification in various observations, but Hendrick Lorenz's idea of space-shortening can be invoked to explain the same phenomenon. Lorenz is . forgotten, because his hypothesis was "useless" in the sense defined by Lakatos: it did not explain anything except the observational data which led to its formulation. Ether is, however, not exactly 1'dead", and a modification of the idea is embedded in Dirac's extension of Maxwell's theory of electromagnetic field. Dirac pictured a collection of vast number of oscillators in a vacuum, each J(enneth J. Hsu 243 of whose energy levels is quantized. Vacuum is thus seething with virtual activity, and there are e.ndless fluctuations in the energy of the field at all points within the space (Coveney and Highfield, 1990). I am now substituting the word chronons in place of Dirac's "oscillators". Moreo,rer, chronons are not only dynamic constituents of electromagnetic waves, they are uniquitous. They could oscillate, they could move as photons, or they could be frozen in a Black Hole. Exothermic reactions in the interior of the Sun are the source of energy reaching the earth. Some 97% of the energy is in the fonn of charged particles and photons. In adopting a cosmological model that the interstellar space of the. universe is filled by dispersions of chronons, I propose that the photons do not travel directly from a source to a monitor, but the)' transfer their energy by collisions and relays. ·The relay model assumes that the energy of a source photon is transmitted by collision to a chronon at rest (or nearly· at rest), causing the latter to be changed into the state of photon motion. The latter serves an energy carrier and transfers the energ)', like the baton of rela)' racers, to the next chronon. The photon that is relieved of its energy would become again a chronon such as a WIMP, but that could become a photon again when it is hit by another photon from behind. A series of equi-distant collisions causes each of the subsequent chronons to become a photon the distance- between successiv·e collisions is the de Broglie wav·e-length of the photon-motion (Coveney and Highfield, 1990). After N number of collisions, the last chronon at rest is converted into a photon whic.h can be detected by a monitor. Light , i.e., a v'ery small fraction of the photons, from the sun is thus transmitted like laser beams, and solar light is a combination of be.ams of different wave lengths. Chronons, being the elementary particles, should have a v'ery high density, certainly not less than the density of neutron stars, 10 14 g/cm3 . Although the mass of a light photon is very small (10- 32 g or less), the gravitional attraction becomes appreciable just before and after the collision when chronons come very, very close together. The driving forces of the movement of photons in a relay of collisions are impact but also gravitation plays a role, especially when chronons are very close. Dri,1en alternately by the kinetic and the gravitational energy, the movement of photons (T = I c), is analogous to pendulum (T = 2·7fv'L/ fi). The \ \'ave-period T is a function of A and the pendulum-period T a function of arm-length L. Photons move in an E -T "timescape" like roller-coasters, but they do not have a free path: A photon driven by impact energy climbs over the. crest of an energy barrier and falls under the gravitional pull into a trough where it collides and sends the next chronon into photon-motion. The particle which lost its energy is now left behind in the trough, before it is compelled to move forward again by the impact of the photon following. The "timescape" may have high peaks and deep valleys or they are rolling hills. The conservation of action states that E dt=h: the. action is the same to cross from one valley to another, despite the different time and energy requireme.nts. 4. NEUTRINOS, AXIONS, WIMPS, AND MAGNETIC MONOPOLES Some 3o/o of solar energy is released is in the form of the. kinetic energy of neutrinos. Neutrinos mov·e with the spe.ed of light, as verified by the neutrinos from the 1987 supernova, \\'hich reached the earth at about the same time as the optical signal. Neutrinos differ, ho\\'ever, from photons in their non-pe-riodic motion. A neutrino flux from the sun has been ve.rified, 244 TAO, Vol. 7, No.2, June 1996 but is found to be 3 times lower than predicted (Boehm and Vogel, 1992). Is it possible that two-third of the solar neutrinos never reached us? In discussing the dark matter of the universe, the four candidates are light neutrinos, axions, WIMPs, and magnetic monopoles. The electron neutrinos were the obvious choice, but the knowledge that the universe is '•matter-" rather than radiation-dominated suggests that the dominant particles are not moving at or near the speed of light. Astrophysicists preferred, therefore, the candidacy of those not moving relativistically (Krauss, 1990). If WIMPs, or weakly interacting massive particles, were to make up the dark matter in the galactic halo, their expected mean velocity would be about 300 km per second.12 Could we not consider WIMPs one kind of chronons which do not move with the speed of light? When a WIMP is involved in a head-on collision with a nucleus of mass equal to its mass, the

WIMP can transfer all of its energy of motion to the nucleus, which will recoil with the same velocity as the WIMP initially had, just as for billiard balls of equal mass.11 What would happen if a photon or electron neutrino is involved in a head-on collision with a WIMP? 5. THE CONSERVATION OF ACTION The distribution of chronons in vacuum cannot be anisotropic, because speed of light transmission is the same in all directions. Chronons in vacuum cannot be regularly spaced, like atoms in crystals with unit-cell length, because light of different wave lengths are transmitted through the same medium. Nevertheless source photons, characterized by given A and T, retain their identity while their energy is transmitted, thus the distance A and duration T between each collision should be the same. Randomly distributed chronons commonly do not satisfy this requirement, light transmission by photons requires a rare coincidence of regularly spaced collisions. Randomly distributed particles, such as gas molecules in air, move in brownian motion, because the molecules have such a large size that they collide at irregular intervals and are scatterred in various directions. The probability that photons move in a relay as postulated must be very, very small. On the other, a series of periodic collisions could occur by chance if there are very, very many chronons of small enough diameter. With the help of mathematical modelling, one might obtain a solution as to the maximum diameter of the particles and the maximum density of particle-dispersion to permit collisions in the form of wave motion. The very small probability to transmit photons over large distances is the reason why distant stars are almost invisible. Photons at source emit at regular intervals initiate a laser of photons, and their regular motion pave the way for the transmission of a light beam of photons which follow. The conservation of action states: (3) Eq. (3) states the de Broglie relationship between the momentum of moving photon and its associated wave: the wave length of the particle is inversely proportional to its momentum, the constant of proportionality is the Planck's constant. Not all energetic chronons emitted from the sun or stars could transmit their energy as laser beams; chronons commonly collide at random distance without periodicity, or • (4a) 245 (4b) Each delay in collisi0n (s >.\) results in: E2 < E1 and m2 .'v· = m1. c. The quantum of energy being transferred by. c)r the momentum of the energy-carrier is thus dissipated if the motion cannot be periodic. One can conclude, therefore, that much of the solar energy cannot reach us, becat1se it has been dissipated as heat in the interstellar space. Con,1ersely chronons such as WIMPs could also be activated by photon-bombardment to a higher energy state. The conservation of action explains the theoretical and experimental observation in quantum mechanics that "s1nall amounts of energy (E) can be 'borro\ved' t'or a time (tit) when h = (,E) (L\t) (Close, 1983)." A corollary is that the translational kinetic energy of a chronon is dissipated by time. Time seems to have a t'unction analogous to friction (which reduces force F), as a comparison of' the follo\ving relations suggests: h -- t . E F -- 11: N (5) { .. 6) , where JI is coefficient of friction and N nor1nal force. Perpetual rnotion of light depends upon t inifinite number of regular collisions of chronons and is thus for all practical purpose impossible. There is a limit ho""'· far a chronon can travel. We can thus state that the universe is finite: its age and its boundary are defined by the chronons at the farthest outpost. 6. CHRONON CONCEPT AND TIME DILATATION Ti1ne-dilatation in the special theory of relativity states that tirne, as measured in seconds, is velocit)'-dependent. The theory contradicts common sense and contributes to the increasing gap between real-life e-xperience.s and t'undamental laws in physics. An application of tl1e chronon-concept could provide an explanation of this strange phenomenon. Assume- that the distance s and travel time t between the source and the receiver of light propagation across a "timescape" \\1ith characterized l and t is measured by' the number of colliding chronons N: s N(A_), t- N (1) (8) ' ' Equation (8) states that the distance s, ineasured by the same number of colliding chronons (N) is different if s is expressed in centimeters (for photons of different wav·e length A). Likewise the time t, measured by the same number of co11iding chronons is also different if it is expressed in se-conds (for photons of different period T). The speed of light travel remains, howe'\1er, constant, for photons of various wave-lengths and peric)ds: (9) The chronons in \1acuum are assumed to be a compressible 1nedium so that the number of colliding c.hronons between the mo\1ing sourc.e and recei\1er remains constant, or N 1 = N2. For the same velocity, the d·istance or time of light travel between moving objects can be said to remain unchanged if it is measured by a dimensionles number N. The values of /\ in 246 cm . a11d T i11 seconds arc, however, dit'fcrent, dependin.g it· the r·ecei\'er is mo\1ing toVv·ard or away from the source. The values are smalle.r in the fo1-mer case, and such pheonomencln hilS been called blue shift, space-shorte.11ing or time-retardation. The values are larger in the lt.tter case and such pheonornenon has been called redshift, space-shortening or time-retardation. 7. BIG BANG FROM BLACK HOLE Scientists and philosophe.rs from the Occident are fascinated by I-Ching, and I too acquired a re.spect for the ancient af"ter I realized that truth could be perceived by patternrecognition. While knowledge is accumulative in helping us to find truth by the technique C)f digitized seque.ncing I see no reason not to accept the essence of· Zen-Buddhism that truth can be suddenly and intuitively pe1-ceived through the acquisition C)f. z.en (:ffjl), a form of pattern- re.cognition, \vhich is often expressed as metaphors or parable.s. The symbol for the metaphor ying-yang is a circle divided into halves by an s-shaped curve, the black)'ing e:tnd the \\i'hite yang. The)1ing and yang make. up the yuzhou (¥'rn). The two Chinese characters y·u C:lnd zhl)U were antique words no longer in use except in the co1nbined t'orm yuzhou, which means the casinos. The Greek Vt1ord for the unjverse is derived fro1n kosrnos, which sig11ifies order. It is thus not surprising that occidental philosophers studying the cosmos have always looked t'or the order, the cause, . the logical sequencing of· things and e\lents. Only recently did I realize that the Chinese word yu signifies directions, which are spatial attributes and the word zhou signifies past, present, and future, \vhich are attributes ot· time. The 111aking of the compound word reflects the ancient Chinese patternrecognition that the universe consists of space and of time (Li, et al., 1990). The elementclry particles are not only spatial but also temporal. being the quctntum actions. The ying-yang sign symbolizes a universe with a polarity of light and darkness. The idea. is also dee.ply f<)Oted in the Juda-Christian ideology. The first sentences of the Bible tead: "In the beginning the God created the heaven and the earth. And the earth was without form, and \1oid: and darkness was upo11 the face of' the deep. And God said Let there be I 1g . h t ., t . It is not surprising that the Catholic Church is pleased w·ith the Big Bang Theory, \\1hich has been considered a \'erification of the Biblical account of genesis: In the beginning there. was the Big Bang, then there \Vere the photons. After\vards there has been a continuous expansion of light so that photons and chronons hav·e been pushed to the oute.r limit of the. universe; the universe expands \While it ages. Photons are not created out of nothing. Where did the chronons co1ne trom? I found again a 111etaphor from the I-Ching. An observant person 1nay notice that there is a small white dot in the black half and black hole in the white half of the ying-yang symbol, expressing a parable in the Tao-Teh Ching of Lao-tzu: the light is ine\i·itably turned into darkness, and the darkness into light. Ancient Chinese sages seem to tell us that a Black Hole is the origin of the uni\1erse, and the universe is eventually going to fall back into a Black HoJe. This is, of course, the modern paradigm of cosmogeny: The gravitational attraction from a Black Hole is so strong that everything passing near the hole will fall into it, including the photons (Hawking, 1988), v.1hich are chronons that move with the speed of light. Movement requires space. When al 1 the ele.mentary particles lose their d)1namics, they are no longer what they were outside. Photons that are forced to remain stationary become chronons. Fermions, being

J(enneth J. Hsu 247 densely packed aggregates of chronons in the first place, would become even more densely packed. A Black Hole consists thus of chronons at rest (or nearly at rest) held together by gravitational energy. The Hole will grow in size with the entrapment of more light and matter. With the accumulation of an ever increasing number of chronons, continued bombardment by light and matter, and adiabatic heating of the nucleated chronons, a critical point could be eventually reached when a straw breaks the camel's back: the last influx of energy into the Black Hole ignites a Big Bang. . Halton Arp (1987) proposed numerous Small Bangs instead of one Big Bang; he interpreted the high-redshift quasars as having been "created in our universe at a later time than the Big Bang." I see no reason why there should not have been more than one Black Holes, exploding at different times. 8. NEUTRINO CAPTURES AND RADIOACTIVE DECAYS The three kinds of radioactive decays are alpha, beta, and gamma decays, describing respectively the phenomena when a nucleus emits an alpha particle (helium nucleus), an electron, or a gamm-ray. The emitted particles have an energy lower than that of the barrier which should have prevented their escape from the radioactive nuclei. Their escape during decay has been explained in terms of the tunnelling effect Levy-Leblond and Balibar, 1990). The nomenclature is derived from the picture of a particle bumping into a mountain. Finding itself at a lower altitude than the height of the mountain, the ·particle has to tunnel itself through the barrier to come out on the other side. Tunnelling is one way of looking at the situation, an alternative is leap-frogging: the particle got enough energy and jumped across the barrier. In the absence of adequate knowledge, we tend to assume a spontaneity to natural phenomena. A fundamental aim of science is, however, to postulate causes other than divine. The tunnelling (or leap-frogging) effects are processes leading to the effect of decays. What is the cause of the decays? Why should an alpha or beta particle start to "tunnel." When should it "tunnel" its way out? Is it spontaneous, or has there been an accomplice? The current theory for the alpha decay of 238U assumes that an alpha particle will have to make many collision with the "wall of the barrier," but the probability of getting out is very small. The average half-life of the nucleus is thus is very large, or 10 10 years, because of the extremely small probability of getting out. The explanation is a form of circular reasoning. The probability is extremely small because our experiments have found very long halfiife for the decay. We tum around then and tell our students that the long halftife is the result of the very little chance of an alpha-particle to dig a tunnel through (or leap across) the barrier! Is there an alternative to this explanation? Is it possible that a particle does not decay arbitrarily. The observation of a predictable halflife suggests that the decay of radioactive atoms obeys a rule, and the relation is pertaining to time: there is the waiting time, and there is the duration of a collision when extra energy is transmitted from one to another particle to enable the latter to leap across the energy-barrier. I have, therefore, approached the problem from a consideration of the meaning of time, and suggested that natural radioactivity results from chronon-capture (Hsii, 1992). The decay of uranium atom has been described as: • U 238 + x· > Th 234 + alpha-particle (10) ' ' 248 TAO, \trol. 7, No.2, June 1996 Likewise, I have describved beta-decay as the consequence of a collision between a atomic nucleus and a chronon. The. beta and the electron-capture decays of the 4°K nucleus have been expressed by the relations: 40 K + X - 40 Ca + e - (12) In particle-physics literature beta-decay is described as the decay of neutron n° into proton p+ , electron e- and an antineutrino no: (13a) The last term in Eq. (13) is a "book-keeping device." When the beta decay was first discovered a serious problem threatened to undermine the fabric of physics. The charges are conserved during the decay, but the momentum was apparently not conserved. Fac.ed with the observation, physicists had to make a choice: "Either momentum conservation for elementary particles had to be abandoned, or something was being emitted that could not be observ·ed, but which carried off just the right of momentum to make e\'erything to work out right. One of the '1czars'1 of theoretical physic.s in the 1930s, Wo1fgang Pauli, declared that that the second alternative was the only acceptable one. Later, Fermi coinced the name r1ei1t1·ino - Italian for "little neutron" - for the unobserved that must ha\re been emitted in the reaction (Krauss, 1990). 11 Keeping the books on the conser\'ation of the energy balanced, physicist could calculate the energy of the neutrino by rearranging the terms of Eq. (13): 0 + - 0 v ···1 p + e - n Eneutrino - (Eelectron + Eproton - Eneutron) (13b) Rearranging terms in Eq. (1 3a), the beta-decay could be phrased in terms of neutrino capture, or (14) This is, in fact, the third solution to the. problem that "threatened to undermine the fabric of physic.s." The beta-decay of potassium nucleus could be considered an activation through the capture of a neutrino: 4°K+v0 14° Ca+e- (_ 15) Nov.r we can play a mathematical game of comparing Eqs. (1 1) and (15) and conclude. (16) Translated into plain ·spoken words, Eq. (16) states that the chronon captured in the beta-decay is a neutrino. Kenneth J. Hsu 249 That the emission of an electron, as in beta-decay, could be induced by the capture of a neutrino is the basis for experiments to detect solar neutrinos. In experiments to measure the solar flux in the Homestake gold mine, South Dakota, the neutrino target consists of C2Cl4 . Solar neutrinos interact with 37 Cl to create an electron and 37 A. The latter has a halflife of 35 days and its creation has been detected before it decays by electron-capture to form 37 Cl again (Boehm and Vogel, 1992). The Brookhaven experiment is a sufficient demonstration that radioactive decays are not a spontaneous "tunnelling effects;'1 they could be induced by particle-interactions or chronon-captures, and in the case of beta-decay the chronon capture is a neutrino. Are electron-captures spontaneous decaying processes or are they also externally induced? This radioactive process is effected through a capture of an electron by a proton in a nucleus, or (_ 17) One could envision a preprogrammed decay of an electron orbit until an innermost eJectron is absorbed by a nucleus, like an averaged artificial satellite is destined to fall back to the earth. Or one could envision that the fall has been induced by collisions: the electron falls into the neucleus because it has interacted with a neutrino, or (17) Actions on electrons by neutrinos have also been verified by experiments (Bohem and Vogel, 1992). 9. CHRONONS AS TIMERS TO ACTIVATE BIOLOGIC CLOCKS The express.ion biologic clock refers to physiolo.gic phenomena, ranging from the germination of a seed, migration of birds, to the vital decay of an aging organism. Biologic rhythms in us such as the daily sleep-and-wake habit and the monthly menstruation period are well known. Those who have had malaria could marvel at the regularity of its 48-hour or 72-hour rhythm. Even more common are the circadian, lunar or seasonal rhythms in animals and plants (Coveney and Highfield, 1990; Fraser, 1988). There seem to be internal pace-makers in all living organisms. Biologic time is manifested by aging. An amazing fact was discovered that embryonic human cells which kept their normal and constant set of choromosomes could not be cultivated in culture for more than 50 doublings (Hayflick, 1956). The time needed for cell-division is different for various species: the duration of a cycle of cell-division for bacteria asexual reproduction is of the order of 103 seconds, for grass-hopper is 10 4 seconds, for high plants is 105 seconds, and even slower for human beings (Fraser, 1988; Anonymous, 1975). There is furthermore the waiting time. The division, the wait, and the limitation of divisibility seem to be the reason why the maximum life-expectation of Homo sapiens is less than 120 years. The waiting time is not the same for different individuals. The persons who suffer from progeria, one of whom is born after every 80 million births, have a very high rate of cell division so that the aging is accelerated (Mills and Weiss, 1990); a child 10 years of age looks like a 90-year old (Brown, 1992). The waiting time could also be retarded by environmental factors, and. the lifespan of some insects is artificially prolonged 2 or 3 times through such interferences. 250

TAO, Vol. 7 l\1o.2, 4June 1996 An even more mysterious aspect of biologic time is the efficacy of genetic clocks. A few years back, the already dwindling population of panda-bears in southwest China suffered a crisis when the arrow-bamboo plants of the region all flowered and died at about the same time. Bamboo is a grass and commonly reproduces by sprouting of new roots every spring. After a regular interval of numerous years, however, bamboo will bloom when a new generation is seeded. The parent bamboo dies after the bloom, and the daughter continues to produce offsprings every year by sprouting new roots until the time of the next periodic bloom. Species of bambus have waiting intervals ranging from several years to more than a hundred years between successive flowering. The species Phyllostachys bambusoids, for example, was first recorded to flower in China 999 B.C., and plants of that species have bloomed regularly once e\1ery 1 20 years ever since. The remarkable fact is the regularity of the periodicity (Gould, 1 977). Some animals could count too: the periodical cicadas have a 17- or 13-year cycle (Fraser, 1988; Gould, 1977). Their ny·mphs li\1e underground, feeding from tree roots. Then, suddenly, when the period comes, millions of mature nymphs emerge from the ground, they mate, reproduce and die . There is a biologic clock in each ny·mph to count the number of passing years. While the waiting time for the germination of barn bus has a periodicity of 3 x 10 9 seconds, the fastest clocks are timed by the \1ibrations of the atoms and molecules in the skin of human body at 10-16 second in response to ultraviolet radiation. Photosynthetic reactions seem to be regulated by pico-second (10- 12 s) clocks (Fraser, 1 988). Movement of micro-molecular solutes in cells have period of 1 o -7 to 10- 4 sec.and, while cell-division or metabolic turno\1er rates vary from minutes, to hours or days (Fraser, 1988; Margineanu, 1992). What is the carrier of the information that activates the biologic clocks? While the skin molecules vibrating at the frequency of ultraviolet light (10- 16 s) apparently result from the actions by singular chronons of photons, the information-transfer to activate biologic rhythms requires pace-makers with longer periodicity. Cybernetics is the science that investigates infor1nation-transfer and data-processing by living organisms. We are told the amazing facts that a human body has 10 14 cells and the information content of a single cell has been estimated to be about 10 12 bits. The super-computers seem necessary, because living cell is a mar\tel of complex structure and life processes are complicated. Even photosynthesis is not simply a capture of photon at regular intervals: the process in,1olves a whole series of electron-transfers to effect complex biochemical reactions. For cell-divisions, proteins have to be synthesized and many other biochemical reactions will have to take place, a whole series of single or aggregated chronons will have to be captured in a pre-detennined order. The information bits in cells have to be structured into software programs to process information input. Enzymes are catalysts in living cells and they cause and direct numerous chemical reactions that occur in living organisms. I suggested that catalystic reactions are activated b)' chronon-captures (Hsii, 1 992). The law of conservation of action suggests that chronons r•at rest" could b.e agitated into motion by incident photons or other high-energ)' chronons. The theory of chemical resonance suggests that coevalent bonds in organic molecules are stabilized by the resonant energy of harmonic oscillators. The term "chronon-captures1' can be interpreted to signify that the absorption of light, or capture of chronons caused the oscillators to reach an excited state of higher resonant energy, sufficient to break the chemical bonds and thus activate biochemical reactions. Biologic rhythms suggest periodic activation, or periodic arrival of "trains" of energetic chronons to effect a series of chronon-resonance for cell division. The long periodic interval could signify the long waiting time of an unusually energetic e\1ent. J(enneth J. Hsu 251 10. RELEVANCE OF THE CHRONON CONCEPT TO EARTH SCIENCE 10.1 Application of the Chronon Concept to Stuidies of Earthquakes A most difficult task for the earth scientists during the 20th century is an assignment to predict earthquake occurrences. It is commonly assumed that a quake is the consequence of accumulation of stress and strain, but we seem to have reached a limit on what we can do withi this approach of earthquake prediction. Perhaps we should try some outlandish ideas. It is, in fact, not unreasonable to postulate that an earthquake occurs when the steady weakening of the strength of material in a seismically active region reaches a critical degree, while stress and strain accumulated steadily along earthquake faults. It is not the additional gravitational stress of the straw which breaks the camel's back, but the weakening by aging of the camel's bones! If so, we need not only to study the stress and strain induced by movements of lithospheric plates, but also the factors causing gradual reduction of the strength of material in seismic regions (Hsii, 1994). One puzzling aspect in seismology is the unusually small stress-drop after earthquakes, often one or two orders of magnitude less than the strength of rocks measured by experiments. This observation could be invoked to supports the postulate that strength-reduction, rather than excessive stress, is the critical factor in the timing of the earthquake-trigger: rocks are weakening regionally, while stress is accumulating along faults, until a fracture is forn1ed at the epicenter where the strength falls below the critical shear stress. Sudden occurrences of earthquakes could be the catastrophic consequence of a steady state decay of strength, if they could have been induced by anomalous factors of strength-weakening. A special feature of earthquaking is the tremendous rate of energy release. In fact, the inability to distinguish seismic waves generated by atomic bombs and those generated by earthquakes hindered for years the agreement on the moratorium of underground bomb tests. The rapid rele.ase of energy by a fission-bomb is a consequence of a chain reaction. Could there be a chain reaction that is triggered to release the earthquake energy? This line of thought led me to think of electron-capture reactions, such as the decay of 4° K into 40 A. Assuming neutrino interaction for electron-capture decay while keeping the books balanced, we have from Eq. (18), two neutrinos could be released by the capture of one neutrino. Equation (18) is book-keeping; it has been not experimentally verified. If there is such a process, the implications could be dramatic: the geometrical progression that each neutrino interaction breeds two neutrinos points to the possibility of a chain-reaction of neutrino-captures, in the manner of neutron chain-reaction. My colleagues in neutrino physics have discouraged my speculation: the capture crosssection of neutrinos is so extremely small and the reaction postulated in Eq. (18) has not been experimentally verified. There is no scientific evidence that the very slow electron-capture decay of 4° K could have any effect on the strength of potassium-bearing rocks. On the other hand, beta decays with short halflife could be considered neutrino-captures by neutrons with a large cross-sections. Could such processes have a fatal effect in weakening the rocks of a seismicallz active region? One more lesson learned from the studies of neutrino captures ' 252 TAO, Vol. 7, No.2 Jurie 1996 is the difficulty of its detection. The neutrino-capture by 37 Cl could be detected because the daughter product 37 A has a halflife of 35 days. If an neutron of an element capturing a neutrino will produce a daughter produc.t of very short halftife, the neutrino capture cannot be detected by experiment. Ne.vertheless, the ionic bonding in the. solid could be broken to cause the weakening of strength of the crystal. I have experienced in my professional career that some good postulates 1ere first formulated on the basis of wrong reasons. My fanciful idea on neutrino chain-reaction could be utterly wrong. On the. other hand, the possibility that rocks in seismic regions ha\l·e been \veaked by some unkno\\'n nuclear reactions deserves a se.rious consideration, in view of the report of radon anomalies as precussors of earthquakes. The radon anomaly is commonly considered an anomalous 1·elease. The conventional explanation is to assume an unusual escape of radon prior to an earthquake because of microfacturing of the host rock (Deng, el al., 1981). Two arguments could be advanced against this interpretation: First of all the radon-anomaly is not restricted to the zone of earthquake faulting where micro-facturing is expected before the quake. Secondl)1, the radon anomaly is commonly a decrease for 'Ai'eeks, or months before the quake, before a sudde.n rise just before the main shock. If the radon-anomaly precussor is not an anomalous release because of accelerated micro-fracturing, could the anomaly be an indication of an anomalous rate production of radiogenic radon? Could there be a very slight variation in the rate of alpha-decay of uranium? Experimental studies of beta decay of relatively short duration has revealed significant variations of decay rates (Alburgh and Harbottle, 1990). Furthermore, the inconsistent results of 14C dates ha\'e commonly been attributed to variations in the of the production rate of 14C, but such an anomalous rate of production is not manifested by the 10Be re.cord. An alternative is to assume constant production, but a variable rate of the 14c decay-rate during the last 15,000 years. 10.2 Applications of the Chronon Concept to Studies of Natural Radioactivity One of the greatest m)1steries in science. during the recent years was a claim of having suc.cessfully accomplished cold fusion. After the dust has settled down, and the emotion has run its course, the claim has been dismissed, but it is difficult to deny that some form of energy has been produced in the cold-fusion apparatus. when "reports of energy-releasing nuclear reactions at toom temperature pour in from labs around the. world (Holden, 1994). " Could the appreciable production of energy a result of "neutrino chain reactions"? If the rate of radioactive decays could be accelerate.cl appreciably by laboratory techniques, the principle is applicable not only to produce energy, but also deactivate radioactive wastes. From what we know now, the capturing cross-section for neutrinos is extremely small, and no reactors of the world are producing strong enough neutrino beams for any practical application. Recalling the history of investigating neutron-capturing, one could ask if there are slow neutrinos, or WIMPs? One could also ask if neutrinos could be slowed down enough for easier capturing. Furthermore, who are we to underestimate the in\'entive power of the scientists and· technicians of the next century? Faraday and Maxwell never could dream of all the things which our contemporaries are making. J(ennetb J. Hsu 253 11. FALSIFIABILITY OF THE CHRONON CONCEPT Physicists communicate the results of their experiments and observations in a mathematical language which becomes less and less comprehensible to a lay person. Paul Feyerabend (1 987) provoked with an unorthodox view that scienctists invent postulates to contradict common sense. In fact, modem physics is a collection of paradoxes, starting with Planck's recognition of quantum energy. De Broglie gave us the wave/particle duality of light and Schrdinger his cat; the physics of light has become "totally unpicturable. " Heisenberg discovered the uncertain principle, with the same Planck's constant to connect two uncertainties such as momentum/position or energy/ time. Dirac invented positron the antimatter, and it became Feynman's electron moving backward in time! Einstein told a story of the twin paradox, and his space-time concept rendered meaningless the concept of simultaneity. There could be no past, present or future, and time has bec·ome "just a coordinate." It was considered as silly to think about the time before the Big Bang as to ask "for a point on the earth at 91°N latitude (Hawking, 1988)." The word chronon was originally introduced in an effort to understand modem science in terms of classical physics, using the everyday language and referring to daily-life experiences. The chronon theory was formulated on the basis of a postulate that chronon is the quantum action. In defining chronons as the elementary particles of the universe, the theory had to assume that chronon has mass. The corollary is the recognition of the conservation of action, as well as that of matter, energy, and momentum in the quantum world. The concept permits a different perspective of the univ·erse. The elementary particles are actions so that space and time should not be considered empty stages; space and time are the actions which have been conserved in various forms since the First

Actions of the Big Bang. The universe expands and it ages, and its a history is a continuance of actions. Lord Kelvin once said that our knowledge is a most unsatisfactory kind, if it cannot be expressed in numbers. I might add that our knowledge is a most unsatisfactory kind, if it cannot be expressed in written words. The introduction of the chronon theory eliminates the need to invent mathematical codes to avoid explanations for things which we do not understand. A basic postulate of the _theory is the conservation of action, and its predictions are falsifiable. Theoretical physicists could verify if the chronon-theory of light propagation and for the origin of natural radioactivity. Experimental physicists could decide whether the conservation of action makes more sense than their usual mode of "book-keeping" to account for energy balance in nuclear reactions. BiolC?gists could explore if the chronons as infor1nation-carriers have given us the biologic clocks. This article is an abstract of the main conclusions to be presented in a forthcoming book on time and chaos, and I have profited from discussions during the last 4 years with many colleagues in physics, astrophysics, mathematics, chemistry, biophysics, and geophysics. The idea on the conservation of action was inspired by Yuk L. Yong who first suggested to me the importance of understanding Planck's Constant in formulating a physical theory of time. John Schellnhuber helped clarify my thoughts on the role of chronons as the universal elementary particles. Don Anderson, Halton Arp, Paul Feyerabend, Erwin Engeler, Dieter Imboden, Kurt Dressler, Herb Shaw, Wolfgang Berger, Jon Dobson, David Olgaard, Christine and Peter Hsii read a part or the whole .of the various drafts of the manuscript and of the book; their suggestions and comments are much appreciated. REFERENCES Alburgh, D. E., and G. Harbottle, 1990: Half-livers of 44Ti and 20 7Bi. PhJrs. Rev. C, 41 2320-2324. Anonymous, 1 975: Encyclopaedia Britannica. L ife, 13, p. 1083. Arp, H., 1 987: Quasars., Red Shifts and Controversies, Interstella Media, Berkeley, 1 98pp. Boehm, F., and P. Vogel, 1992: Physics of massive neutrinos, Cambridge Univ. Press, Cambridge, UK, 235pp .. Brown, W. T., 1 992: Progeria: A human disease model of accelerated aging. Am . J. (!Jin. Nu tr., 55, 1 222S-1 2·24s . Close, F., 1983: The Cosmic Onion. Am. Inst. Physics, New York 1 87pp .. Coveney, P., and R. Highfield, 1990: The Arro\v of Time, Fa\vcett Columbine, New York, 378pp .. Davies, P. C. W., 1 990: The Physics of Time Assymmetry, Univ. Calif. Press, Berkeley, 214pp .. Deng, Q. P., L. Jones, and P. Molnar, 1 981: Earthquake Prediction, American Geophysical Union, Washington, D. C., 543-565. Diirrenmatt, F., 1988: Vergangenheit und Bild. Gesammelte Werke. Gesamm elte Werke, 6, 57-66, Diogenes ; Zurich. E'1erett III, Hugh, 1 957: "Relative state" formulation of quantum mechanics. Rev. Mod. Phvsics, 29, 454-462. Feyerabend, P., 1 987: Farewell to Reason, Verson, New Yorrk, 327pp .. Fraser ; J. T. , 1 988: Die Zeit, Birkhauser, Basel, 479pp .. Gardner, M., 1992: Fractal Music, Hypercards, and More ... , Free.man, New York 327pp . . Gould, S., 1 977: Ever Since Darwin, Norton, New York, 285pp .. Hawking, S. , 1988: A Brief History of Tin1 e, Bantam Press, London, 198pp .. Hayflick, L., 1956: The limited in-vitro lifetime of human diploid cell strains. Exp. Cell R. es., 37, 614-636. Holden, C., 1 994: News and comments. l5ci e11ce, 264, p.771. Hsii, K. J., 1 992: In search of a physical theory of time. P1-oc. Natl. r1.ca(l. Sci., 89, 1 0222-10226. Hsii, K. J., 1994: An atomistic approach to study earthquakes. B ull. Tech . Lrni\t. Ista.nb ul, 47, 281-293. Krauss, L. M., 1 990: The Fifth Essence, Basic Books, Inc., Publishers, New York, 342pp .. Lee, T. D., 1983: Can time be a discrete dynamical variable. Phys . Lett., 122B, 217-224. Levy-Leblond, J., and F. Balibar, 1990: Quantics, North Holland, Amsterdam, 539pp .. Li, X., Z. Duan, and D. Xu, 1 990: I-Ching and Modem Science (in Chinese), Social Science Publications, Beijing, 379pp .. Margenau fl., 1 977: The Nature of Physical Reality, Ox Bow Press, Woodbridge, Conn., 479pp .. Margineanu. D. G .1992: Dimensiona]ity, time-sca]e.s and membrane . . J. Tl1tor. Biol., 164, 403-406. Mil ls, R. G. and

A. S. Weiss, 1 990: Does progeria provide the best method of accelerated ageing in humans . (;ervnt<.>ll)g.}', 36, 84-98. Weinberg S., 1 994: Dreams of a final theoy, Vintage Books, New York, 340pp .. •

Reference 2:
arXiv:gr-qc/0206078v2 30 Oct 2003 TIME, CLOSED TIMELIKE CURVES AND CAUSALITY F. LOBO1 AND P. CRAWFORD2 Centro de Astronomia e Astrof´ısica da Universidade de Lisboa Campo Grande, Ed. C8 1749-016 Lisboa, Portugal 1. Introduction It seems to be extremely difficult to give a precise definition of Time, this mysterious ingredient of the Universe. Intuitively, we have the notion of time as something that flows. Ancient religions have registered it as something unusual, and many myths are built into their dogmas. The ancient Greeks conveyed the image of Chronos, or Father Time. Plato assumed that time had a beginning, looping back into itself. This notion of circular time, was probably inspired by phenomena observed in Nature, namely the alternation of day and night, the repetition of the seasons, etc. But, it was in the Christian theological doctrine that the unique character of historical events gave rise to a linear notion of time. Aristotle, a keen natural philosopher, stated that time was related to motion, i.e., to change. An idea reflected in his famous metaphor: Time is the moving image of Eternity. Reflections on time can be encountered in many philosophical considerations and works over the ages, culminating in Newton's Absolute Time. Newton stated that time flowed at the same rate for all observers in the Universe. But in 1905, Einstein changed altogether our notion of time. Time flowed at different rates for different observers, and Minkowski, three years later, formally united the parameters of time and space, giving rise to the notion of a four-dimensional entity, spacetime. Later, Einstein influenced by Mach's Principle, was motivated to seek a theory in which the structure of spacetime was influenced by the presence of matter, and presented the field equations of the General Theory of Relativity in 1915. Adopting a pragmatic point of view, to measure time a changing configuration of matter is needed, i.e., a swinging pendulum, etc. Change seems to be imperative to have an emergent notion of time. 2 F. LOBO1 AND P. CRAWFORD2 Therefore, time is empirically related to change. But change can be considered as a variation or sequence of occurrences. Thus, intuitively, a sequence of successive occurrences, provides us with a notion of something that flows, i.e., it provides us with the notion of Time. Time flows and everything relentlessly moves along this stream. In Relativity, we can substitute the above empirical notion of a sequence of occurrences by a sequence of events. We idealize the concept of an event to become a point in space and an instant in time. Following this reasoning, a sequence of events has a determined temporal order. We experimentally verify that specific events occur before others and not vice-versa. Certain events (effects) are triggered off by others (causes), providing us with the notion of causality. 2. Closed Timelike Curves and Associated Paradoxes of Time Travel The conceptual definition and understanding of Time, both quantitatively and qualitatively is of the utmost difficulty and importance. Special Relativity provides us with important quantitative elucidations of the fundamental processes related to time dilation effects. The General Theory of Relativity (GTR) provides a deep analysis to effects of time flow in the presence of strong and weak gravitational fields. As time is incorporated into the proper structure of the fabric of spacetime, it is interesting to note that GTR is contaminated with non-trivial geometries which generate closed timelike curves [1]. A closed timelike curve (CTC) allows time travel, in the sense that an observer which travels on a trajectory in spacetime along this curve, returns to an event which coincides with the departure. The arrow of time leads forward, as measured locally by the observer, but globally he/she may return to an event in the past. This fact apparently

violates causality, opening Pandora's box and producing time travel paradoxes [2], throwing a veil over our understanding of the fundamental nature of Time. The notion of causality is fundamental in the construction of physical theories, therefore time travel and its associated paradoxes have to be treated with great caution. The paradoxes fall into two broad groups, namely the consistency paradoxes and the causal loops. The consistency paradoxes include the classical grandfather paradox. Imagine travelling into the past and meeting one's grandfather. Nurturing homicidal tendencies, the time traveller murders his grandfather, preventing the birth of his father, therefore making his own birth impossible. In fact, there are many versions of the grandfather paradox, limited only by one's imagination. The consistency paradoxes occur whenever possibilities of changing events in the past arise. The paradoxes associated with causal loops are related to self-existing information or objects, trapped in spacetime. Imagine a time traveller going back to his past, handing his younger self a manual for the construction of a time machine. The younger version then constructs the time machine over the years, and eventually goes back to the past to give the manual to his younger self. The time machine exists in the future because it was constructed in the past by the younger version of the time traveller. The construction of the time machine was possible because the manual was received from the future. Both parts considered by themselves are consistent, and the paradox appears when considered as a whole. One might inquire as to the origin of the manual, since its worldline is a closed loop. There is a manual never created, nevertheless existing in spacetime, although there are no causality violations. 3. Solutions of the EFEs Generating CTCs A great variety of solutions to the Einstein Field Equations (EFEs) containing CTCs exist, but two particularly notorious features seem to stand out. Solutions with a tipping over of the light cones due to a rotation about a cylindrically symmetric axis; and solutions that violate the Energy Conditions of GTR, which are fundamental in the singularity theorems and theorems of classical black hole thermodynamics [3]. 3.1. STATIONARY, AXISYMMETRIC SOLUTIONS The tipping over of light cones seem to be a generic feature of some solutions with a rotating cylindrical symmetry. The general metric for a stationary, axisymmetric solution with rotation is given by [1, 4]: $ds2 = -A(r)dt2 + 2B(r)d\phi\, dt + C(r)d\phi 2 + D(r)(dr2 + dz2)$ (1) The range of the coordinates is: $t \in (-\infty, +\infty)$, $r \in (0, +\infty)$, $\phi \in [0, 2\pi]$, and $z \in (-\infty, +\infty)$, respectively. The metric components are functions of r alone. It is clear that the determinant, $g = \det(g\mu\nu) = -(AC + B2)D2$ is Lorentzian, provided that $(AC + B2) > 0$. Due to the periodic nature of the angular coordinate, ϕ, an azimuthal curve with $\gamma = \{t = const, r = const, z = const\}$ is a closed curve of invariant length $s\ 2\ \gamma \equiv C(r)(2\pi)\ 2$. If C(r) is negative then the integral curve with (t, r, z) fixed is a CTC. The present work is far from making an exhaustive search of all the EFE solutions generating CTCs with these features, but the best known spacetimes will be briefly analyzed, namely, the van Stockum spacetime, the G¨odel universe and spinning cosmic strings. 3.1.1. Van Stockum Spacetime The earliest solution to the EFEs containing CTCs, is probably that of the van Stockum spacetime [1, 5]. It is a stationary, cylindrically symmetric solution describing a rapidly rotating, infinitely long cylinder of dust, surrounded by vacuum. The centrifugal forces of the dust are balanced by the gravitational attraction. Consider R the surface of the cylinder. The metric for the interior solution $r < R$, is given by: $ds2 = -dt2 + 2\omega r2\, d\phi\, dt + r\ 2\ (1 - \omega\ 2\ r\ 2\ )d\phi 2 + \exp(-\omega\ 2\ r\ 2\ )(dr2 + dz2)$ (2) where ω is the angular velocity of the cylinder. It is trivial to verify that CTCs arise if $\omega r > 1$. Causality violation can also be verified for $\omega R > 1/2$, in the exterior region. 3.1.2. Spinning Cosmic String Consider an infinitely long straight string that lies along and spins around the z-axis. The symmetries are analogous to the van Stockum spacetime, but the asymptotic behavior is different [1]. We restrict the analysis to an infinitely long straight string, with a deltafunction source confined to the z-axis. It is characterized by a mass per unit length, μ; a tension, τ , and an angular momentum per unit length, J. In cylindrical coordinates the metric takes the following form: $ds2 = -[d(t + 4GJ\phi)]2 + dr2 + (1 - 4G\mu) 2 r 2 d\phi2 + dz2$ (3) Consider an azimuthal curve, i.e., an integral curve of ϕ. Closed timelike curves appear whenever $r < 4GJ/(1 - 4G\mu)$. 3.1.3. The G¨odel Universe Kurt G¨odel in 1949 discovered an exact solution to the EFEs of a uniformly rotating universe containing dust and a nonzero cosmological constant. Writing the metric in a form in which the rotational symmetry of the solution, around the axis r = 0, is manifest and suppressing the irrelevant z coordinate, we have [3, 6]: $ds2 = 2w -2 (-dt'2 + dr2 - (\sinh4 r - \sinh2 r) d\phi2 + 2(\sqrt{}2) \sinh2 r\, d\phi\, dt)$ (4) Moving away from the axis, the light cones open out and tilt in the ϕdirection. The azimuthal curves with $\gamma = \{t = const, r = const, z = const\}$ are CTCs if the condition $r > \ln(1 + \sqrt{}2)$ is satisfied. 3.2. SOLUTIONS VIOLATING THE ENERGY CONDITIONS The traditional manner of solving the EFEs, $G\mu\nu = 8\pi GT\mu\nu$, consists in considering a plausible stress-energy tensor, $T\mu\nu$, and finding the geometrical structure, $G\mu\nu$. But one can run the EFE in the reverse direction by imposing an exotic metric $g\mu\nu$, and eventually finding the matter source for the respective geometry. In this fashion, solutions violating the energy conditions have been obtained. One of the simplest energy conditions is the weak energy condition (WEC), which states: $T\mu\nu U\ \mu U\ \nu \geq 0$, in which $U\ \mu$ is a timelike vector. This condition is equivalent to the assumption that any timelike observer measures a local positive energy density. Although classical forms of matter obey these energy conditions, violations have been encountered in quantum field theory, the Casimir effect being a well-known example. Adopting the reverse philosophy, solutions such as traversable wormholes, the warp drive, the Krasnikov tube and the Ori-Soen spacetime have been obtained. These solutions violate the energy conditions and with simple manipulations generate CTCs. 3.2.1. Traversable Wormholes, the Gott Spacetime and the Ori-Soen Solution Much interest in traversable wormholes had been aroused since the classical article by Morris and Thorne [7]. A wormhole is a hypothetical tunnel which connects different regions in spacetime. These solutions are multiplyconnected and probably involve a topology change, which by itself is a problematic issue. One of the most fascinating aspects of wormholes is their apparent ease in generating CTCs. There are several ways to generate a time machine using multiple wormholes [1], but a manipulation of a single wormhole seems to be the simplest way [8]. An extremely elegant model of a time-machine was constructed by Gott [9]. It is an exact solution to the EFE for the general case of two moving straight cosmic strings that do not intersect. This solution produces CTCs even though they do not violate the WEC, have no singularities and event horizons, and are not topologically multiply-connected as the wormhole solution. The appearance of CTCs relies solely on the gravitational lens effect and the relativity of simultaneity. A time-machine model was also proposed by Amos Ori and Yoav Soen which significantly ameliorates the conditions of the EFE's solutions which generate CTCs [10]. The Ori-Soen model presents some notable features. It was verified that CTCs evolve from a well-defined initial slice, a partial Cauchy surface, which does not display causality violation. The partial Cauchy surface and spacetime are asymptotically flat, contrary to the Gott spacetime, and topologically trivial, contrary to the wormhole solutions. The causality violation region is constrained within a bounded region of space, and not at infinity as in the Gott solution. The WEC is satisfied until and beyond a time slice $t = 1/a$, on which the CTCs appear. 3.2.2. The Alcubierre Warp Drive and the Krasnikov Solution Within the framework of general relativity, it is possible to warp spacetime in a small bubblelike region [11], in such a way that the bubble may attain arbitrarily large velocities, v(t). Inspired in the inflationary phase of the early Universe, the enormous speed of separation arises from the expansion of spacetime itself. The model for hyperfast travel is to create a local distortion of spacetime, producing an expansion behind the bubble, and an opposite contraction ahead of it. One may consider a spaceship immersed within the bubble, moving along a timelike curve, regardless of the value of v(t). Due to the arbitrary value of the warp bubble velocity, the metric of the warp drive permits superluminal travel. This possibility raises the question of the existence of CTCs. Although the solution deduced by Alcubierre by itself does not possess CTCs, Everett demonstrated that these are created by a simple modification of the Alcubierre metric [12], by applying a similar analysis as in tachyons. Krasnikov discovered an interesting feature of the warp drive, in which an observer in the center of the bubble is causally separated from the front edge of the bubble. Therefore he/she cannot control the Alcubierre bubble on demand. Krasnikov proposed a two-dimensional metric [13], which was later extended to a four-dimensional model [14]. Using two such tubes it is a simple matter, in principle, to generate CTCs. 4. Conclusion GTR has been an extremely successful theory, with a well established experimental footing, at least for weak gravitational fields. Its predictions range from the existence of black holes and gravitational radiation to the cosmological models, which predict a primordial beginning, namely the bigbang. However, it was seen that it is possible to find solutions to the EFEs, with certain ease, which generate CTCs. This implies that if we consider GTR valid, we need to include the possibility of time travel in the form of CTCs. A typical reaction is to exclude time travel due to the associated paradoxes. But the paradoxes do not prove that time travel is mathematically or physically impossible. Consistent mathematical solutions to the EFEs have been found, based on plausible physical processes. What they do seem to indicate is that local information in spacetimes containing CTCs are restricted in unfamiliar ways. The grandfather paradox, without doubt, does indicate some strange aspects of spacetimes that contain CTCs. It is logically inconsistent that the time traveller murders his grandfather. But, one can ask, what exactly TIME, CLOSED TIMELIKE CURVES AND CAUSALITY 7 prevented him from accomplishing his murderous act if he had ample opportunities and the free will to do so. It seems that certain conditions in local events are to be fulfilled for the solution to be globally self-consistent. These conditions are denoted consistency constraints [15]. To eliminate the problem of free will, mechanical systems were developed, such as the selfcollision of billiard balls in the presence of CTCs [16]. These do not convey the associated philosophical speculations on free will related to human beings. Much has been written on two possible remedies to the paradoxes, namely the Principle of Self-Consistency and the Chronology Protection Conjecture. Igor Novikov is a leading advocate for the Principle of Self-Consistency, which stipulates that events on a CTC are self-consistent, i.e., events influence one another along the curve in a cyclic and self-consistent way. In the presence of CTCs the distinction between past and future events is ambiguous, and the definitions considered in the causal structure of well-behaved spacetimes break down. What is important to note is that events in the future can influence, but cannot change, events in the past. The Principle of Self-Consistency permits one to construct local solutions of the laws of physics, only if these can be prolonged to a unique global solution, defined throughout non-singular regions of spacetime. Therefore, according to this principle, the only solutions of the laws of physics that are allowed locally, reinforced by the consistency constraints, are those which are globally self-consistent. Hawking's Chronology Protection Conjecture is a more conservative way of dealing with the paradoxes. Hawking notes the strong experimental evidence in favour of the conjecture from the fact that "we have not been invaded by hordes of tourists from the future" [17]. An analysis reveals that the renormalized expectation value of the quantum stress-energy tensor diverges as one gets close to CTC formation. This conjecture permits the existence of traversable wormoles, but prohibits the appearance of CTCs. The transformation of a wormhole into a time machine results in enormous effects of the vacuum polarization, which destroys its internal structure. There is no convincing demonstration of the Chronology Protection Conjecture, but the hope exists that a future theory of quantum gravity may prohibit CTCs. In addition to these remedies, Visser considers two other conjectures [1]. The first is the radical reformulation of physics conjecture, in which one abandons the causal structure of the laws of physics and allows, without restriction, time travel, reformulating physics from the ground up. The second is the boring physics conjecture, in which one simply ceases to consider the solutions to the EFEs generating CTCs. Perhaps an eventual quantum gravity theory will provide us with the 8 F. LOBO1 AND P. CRAWFORD2 answers. But, as stated by Thorne [18], it is by extending the theory to its extreme predictions that one can get important insights to its limitations, and probably ways to overcome them. Therefore, time travel in the form of CTCs is more than a justification for theoretical speculation, it is a conceptual tool and an epistemological instrument to probe the deepest levels of GTR and extract clarifying views. References 1. Visser, M. (1995) Lorentzian Wormholes: From Einstein to Hawking, American Institute of Physics, New York. 2. Nahin, P.J. (1999) Time Machines: Time Travel in Physics, Metaphysics and Science Fiction, Springer-Verlag and AIP Press, New York. 3. Hawking, S.W. and Ellis, G.F.R. (1973) The Large Scale Structure of Spacetime, Cambridge University Press, London. 4. Wald, R.M. (1984) General Relativity, University of Chicago Press, Chicago. 5. Tipler, F.J. (1974) Rotating cylinders and the possibility of global causality violation, Physical Review, D9, 2203-2206. 6. G¨odel, K. (1949) An example of a new type of cosmological solution of Einstein's field equations of gravitation, Reviews of Modern Physics, 21, 447-450. 7. Morris, M. and Thorne, K.S. (1988) Wormholes in spacetime and their use for interstellar travel: a tool for teaching general relativity, American Journal of Physics 56, 395-412. 8. Morris, M., Thorne, K.S. and Yurtsever, U. (1988) Wormholes, time machines and the weak energy condition, Physical Review Letters 61, 1446-1449. 9. Gott, J.R. (1991) Closed timelike curves produced by pairs of moving cosmic strings: exact solutions, Physical Review Letters 66, 1126-1129. 10. Soen, Y. and Ori, A. (1994) Causality violation and the weak energy condition, Physical Review D 49, 3990-3997. 11. Alcubierre, M. (1994) The warp drive: hyper-fast travel within general relativity, Classical Quantum Gravity 11, L73-L77. 12. Everett, A.E. (1996) Warp drive and causality, Physical Review D 53, 7365-7368. 13. Krasnikov, S.V. (1998) Hyper-fast interstellar travel in general relativity, Physical Review D 57, 4760. 14. Everett, A.E. and Roman, T.A. (1997) A superluminal subway: the Krasnikov tube, Physical Review D 56, 2100. 15. Earman, J. (1995) Bangs, Crunches, Whimpers, and Shrieks: Singularities and Acausalities in Relativistic Spacetimes, Oxford University Press. 16. Echeverria, F.G., Klinkhammer, G. and Thorne, K.S. (1991) Billiard balls in wormhole spacetimes with closed timelike curves, Physical Review D 44, 1077-1099. 17. Hawking, S.W. (1992) Chronology protection conjecture, Physical Review D 56, 4745-4755. 18. Thorne K.S. (1992) Closed Timelike Curves, General Relativity and Gravitation 1992, Gleiser, J.L., et al. eds, Institute of Physics, Bristol.

Reference 3:

Models of Time Travel and their Consequences Cover Page Footnote Submitted as a requirement in fulfillment of Oglethorpe University's certificate honors program. Committee: Keith Aufderheide, John Cramer, Michael Rulison This article is available in Oglethorpe Journal of Undergraduate Research: https://digitalcommons.kennesaw.edu/ojur/vol5/iss2/1 "How wonderful that we have met with a paradox. Now we have some hope of making progress." Neils

Bohr Defining Time and Einstein's Universe Introduction This is not an attempt to prove that time travel is possible. Rather, I am going to start with the assumption that time travel is possible under certain conditions of relativity that will be outlined, and then proceed to argue for three possible models of time. I will then outline a list of experiments that would either lend credibility to, or discredit, the three models. The reader might question, "Why three models?" As will be seen, these are the only three logically sound, or realistically possible, models that can exist under my assumptions. I fully invite any reader to provide another rational model under the same conditions I have assumed.1 Lastly, this work is intended to be for a general audience just as much as it is intended for the reader who has studied the topic before. Definitions, Definitions, Definitions Like many other works about time, this will also begin with the obligatory section on "what do you mean when you say 'time travel.'" Putting a direct definition on time has been a struggle for physicists and philosophers for quite a long while now. Many people in the science community are happy to say that time is a useful mathematical tool as a fourth dimension, and mankind has been measuring time throughout the majority of recorded history, but how can we measure something that we cannot touch, or feel, or smell, or taste? 1 In fact, if the reader is successful in this, please make an attempt to contact me. The way of looking at time that lasted for the longest period was Isaac Newton's definition (1687). He made a distinction between two different types of time: absolute time and relative time. The first was absolute time. Absolute time existed without regard to man or the universe and flowed independent of space or motion – as physicist Michio Kaku once called it, "God's wristwatch." Newton's second type of time was called relative time. Although it has nothing to do with Einstein's relativity, Netwon's relative time was the quantifiable time and was only measured by the duration of motion of objects. Newton's definition of time was accepted as the outright definition by the world at large, that is until Einstein redefined how we pictured time in 1905. Einstein not only suggested that observers traveling at different speeds recorded different lengths of time between the same two events, but he also argued that space and time were connected – the exact opposite of Newton's first definition. It is under Einstein's relativistic world where we will begin. Einstein's Realization that Time and Space are Related The story says that Einstein was riding on a trolley-car in Bern, Switzerland and watching the clocktower as he was riding away from it. He started to think what he would see on the face of the clock if he were suddenly propelled away from it at the speed of light. He concluded that he would follow along with the photons that bounced off the face of the clock, since they too travel at the speed of light, and that he would never witness the hands tick. In a sense, traveling at the speed of light, an observer would observe time to stand still. However, imagine that you are floating still in the dead of space. You are obviously not moving through any spatial coordinates, but what you are doing is solely traveling through time. This is what mathematicians and physicists mean when they refer to time as a fourth dimension. Taking these two circumstances into consideration, we have a decent picture of how space and time are related in Einstein's universe. That is, one has the option of not traveling through space but traveling one hundred percent through time, but as one starts to move faster and faster (approaching speeds up to the speed of light), one starts to move less and less through time and only through space. In this respect, if you would like to measure a longer amount of time between two events than someone who is sitting down, simply go for a walk. Another important aspect of Einstein's universe is the disproof of simultaneity. The situation, well known to students of relativity, has one observer sitting on a train that is moving close to the speed of light and a second observer sitting stationary on the outside of the tracks. At the moment the midpoint of the train passes by the stationary observer, miraculously both ends of the train are struck by two different lightning bolts. The stationary observer says that both ends of the train were struck at the same time, or that there was a time difference between the two events of zero. However, the conductor on the train, since the train is headed in one direction (toward the light in the front and away from the light in the back), sees the light from the front end first, and then sees the light from the second end, i.e. the observer on the train says that the front end of the train was struck first, then the back end, or that there is a time difference. Through this story, Einstein shows that there cannot be anything described as "simultaneous" because observers traveling at different speeds will measure different lengths of time occurring between different events.2 Speed is not the only thing that affects space and time in Einstein's universe. Mass as well can warp the two. This was demonstrated experimentally when it was confirmed that large objects, 2 The role of light and some other consequences of Einstein's universe that specifically relate to this can be found in Mook, Delo. Vargish, Thomas. "Special Theory of Relativity." In Inside Relativity, 85 – 95. Princeton, New Jersey: Princeton University Press, 1987. such as the sun, could deflect starlight. In fact, all objects within a gravitational field are subject to "artificial" fields of curved space-time.3 So, in Einstein's universe, just as you would measure longer time between two events taking a walk than you would sitting down, you would also measure longer time closer to a large mass. This has been experimentally shown by putting identical clocks on the surface of the earth and on a plane that flies around the world – indeed it was shown that the clocks showed different times. Even clocks on GPS satellites are calibrated to run at about 7 microseconds faster than clocks on the surface of Earth to account for relativistic time dilation.4 Time as a River One of the largest assumptions that I am going to make is that time functions like a river, with all points moving forward together simultaneously. The points in time are not necessarily moving forward at the same speed, but what I want to point out is that there is a specific direction.5 To argue for this, I will invoke our shared experience as human beings. We have always observed time to travel from the past to present and this is what I will refer to as time's distinct direction – I will refer to this as "forward" in time. The reader might be inclined to ask questions like "How wide is the river?" or "What is the source of the river?" But these questions are taking the metaphor too literally and running with it. The point of the river analogy is to illustrate that time has a direction and appears to flow. How I want to think of time, then, is as a string of (possibly) infinite "presents" that are all moving forward together. 3 Gibilisco, Stan. "The Principle of Equivalence" In Understanding Einstein's Theories of Relativity, 142 – 153. New York, New York: Dover Publications Inc, 1983. 4 Pogge, Richard. "Real-World Relativity: the GPS Navigation System." Astronomy Ohio State. April 10, 2014. Accessed April 12, 2015. http://www.astronomy.ohio-state.edu/~pogge/Ast162/Unit5/gps.html. 5 For a detailed article providing evidence to argue this claim, see "On Time Travel" by John Cramer. Words of Warning Henceforth, we can consider any time travel forward in time as being plucked from a certain point in the river, letting that time carry on, and being placed back in at a later point. Instantaneous time travel forward in time creates some issues that I will get into later. Travel into the past, then, can be considered as the ability to travel backward in our river. This is where things get more complicated. Where in travel to the future we can easily imagine ourselves being "removed from time" and being placed back in at a later point, travel into the past brings up issues such as the famous grandfather paradox.6 The conclusion to this apparent paradox will be an important differentiation between two of the proposed models of time. To put it another way, the question of whether or not a traveler to the past can kill his or her grandfather has a binary answer: yes or no. Again, this will be an important distinction in definitions to come. A Brief Note on the Present Understanding what "now" means can be difficult. If time is a continuum that matter moves through from the past into the future, then "the present" is a term that has little meaning because that singular point in time is perpetually at a different place. If, however, as some scientists are inclined to believe, time is quantized, "now" has a different meaning. If time is quantized, then that means that time moves forward in distinct undividable increments – this unit has been 6 In case you are unfamiliar with the idea, the grandfather paradox was first posited by Nat Schachner in the short story Ancestral Voices (1933). It says that if you were able to go back in time and then killed your grandfather, you would never then be born. On the flipside, if you are never to be born, then it is impossible for you to go back in time and kill your grandfather. 5 Mantica: Models of Time Published by DigitalCommons@Kennesaw State University, 2015 labeled a chronon. There is a sizeable amount of of the present, as we shall see. On the Nature of the Machine In 1974 physicist Frank Tipler showed that a solution to the equations of general relativity could be found in an infinitely spinning about its central axis. He showed that observers traveling at sub light speeds near the cylinder could end up traveling back in time Figure 1). Now, the full description of how explained using Minkowski "light in a moment, but here I want to talk about how understanding of what it means to "travel through Like in the Tipler Cylinder, the most realistic models of time travel will warping of space-time. One possibility ring made of an incredibly dense material time around the traveler within the ring. A third theorized machine, or method, of traveling through time would be traveling through a wormhole. Einstein and Rosen proposed that wormholes could exist that fun between two otherwise inaccessible parts of the universe 7 For a detailed description of Tipler Cylinders and how they are explained by Minkowski diagrams, I recommend Nahin, Paul. "Tipler's Time Machine." In Springer-Verlag New York Inc, 1999. Figure zeable amount of research going on today to discover the nature achine In 1974 physicist Frank Tipler showed that a solution to the equations of general relativity could be found in an infinitely long cylinder that was spinning about its central axis. He showed that observers traveling at sub light speeds near the cylinder could end up traveling back in time Now, the full description of how Tipler came to this conclusion can be explained using Minkowski "light-cone" diagrams. These will be explained I want to talk about how the method of traveling through time effects our understanding of what it means to "travel through time."7 Like in the Tipler Cylinder, the most realistic models of time travel will likely involve the One possibility of achieving time travel is often characterized as a large ring made of an incredibly dense material – so dense, in fact, that it has the ability to warp space time around the traveler within the ring. machine, or method, of traveling through time would be traveling through a wormhole. Einstein and Rosen proposed that wormholes could exist that functioned as links between two otherwise inaccessible parts of the universe. In this model, two "throats" of two For a detailed description of Tipler Cylinders and how they are explained by Minkowski diagrams, I recommend Nahin, Paul. "Tipler's Time Machine." In Time Machines, 92 – 95. Springer-Verlag, New York: Figure 1 research going on today to discover the nature In 1974 physicist Frank Tipler showed that a solution to the equations of long cylinder that was spinning about its central axis. He showed that observers traveling at sublight speeds near the cylinder could end up traveling back in time (See Tipler came to this conclusion can be These will be explained the method of traveling through time effects our involve the characterized as a large in fact, that it has the ability to warp spacemachine, or method, of traveling through time would be traveling through a ctioned as links . In this model, two "throats" of two For a detailed description of Tipler Cylinders and how they are explained by Minkowski diagrams, I Verlag, New York: 6 Oglethorpe Journal of Undergraduate Research, Vol. 5 [2015], Iss. 2, Art. 1 https://digitalcommons.kennesaw.edu/ojur/vol5/iss2/1 wormholes meet at two oppositely charged elementary particles, and this warps space There is still much not understood about the nature of interact with them – some scientists suggest they might lead to parallel universes. this might imply that if scientists were to create a wormhole successfully, we would only be able to access one point in space or time. Minkowski Diagrams that the object takes to complete that trajectory. It is easy to imagine now, this diagram rotated three hundred and sixty degrees about the time axis, creating a two-dimensional spatial pla discussions of time travel because they are a convenient way of drawing out an object's future 8 For a fuller description of Einstein Light: Superluminal Loopholes in Physics 9 Minkowski diagrams are very helpful in resolving special relativity's Twin Paradox. See the previously referenced Nahin's "Proper Time, Curved World Lines, and the Twin Paradox" in Figure 2 wormholes meet at two oppositely charged elementary particles, and this warps space There is still much not understood about the nature of wormholes and how we would be able to some scientists suggest they might lead to parallel universes. this might imply that if scientists were to create a wormhole successfully, we would only be able time. Also called space-time diagrams, Minkowski diagrams are a very helpful tool in describing situations involving the change of space and time. A very simple diagram is shown in Figure 2. In these diagrams, distance is g horizontal axis and time (typically represented as c*t) is on the vertical. The line represented on the graph is the "worldline" of light. In space-time diagrams, worldlines specific object's trajectory and the amount of time that the object takes to complete that trajectory.9 It is easy to imagine now, this diagram rotated three hundred and sixty degrees about the time dimensional spatial plane and a "light cone." Light cones are useful in discussions of time travel because they are a convenient way of drawing out an object's future For a fuller description of Einstein-Rosen wormholes, see Herbert, Nick. "Space Warps." In Light: Superluminal Loopholes in Physics, 98 - 129. New York, New York: Plume, 1989. Minkowski diagrams are very helpful in resolving special relativity's Twin Paradox. See the previously referenced Nahin's "Proper Time, Curved World Lines, and the Twin Paradox" in Time Machines wormholes meet at two oppositely charged elementary particles, and this warps space-time.8 wormholes and how we would be able to some scientists suggest they might lead to parallel universes. What is more, this might imply that if scientists were to create a wormhole successfully, we would only be able time diagrams, Minkowski diagrams are a very helpful tool in describing situations involving the change of space and time. A very simple diagram is shown in Figure In these diagrams, distance is given on the horizontal axis and time (typically represented as c*t) is on the vertical. The line represented on the graph is the "worldline" of light. time diagrams, worldlines symbolize a s trajectory and the amount of time It is easy to imagine now, this diagram rotated three hundred and sixty degrees about the time ne and a "light cone." Light cones are useful in discussions of time travel because they are a convenient way of drawing out an object's future Herbert, Nick. "Space Warps." In Faster Than Minkowski diagrams are very helpful in resolving special relativity's Twin Paradox. See the previously Time Machines, pages 459 – 466. 7 Mantica: Models of Time Published by DigitalCommons@Kennesaw State University, 2015 (and also past). Consider two objects, then, in the same spatial plane that are a certain distance apart from each other. Both objects have a light cone, but the two objects are incapable of seeing each other until the time that their light cones cross. To put it more simply in an example: it takes time for light to travel from the sun to reach the earth (about eight minutes). Hence, if the sun suddenly went out, it would take observers on Earth eight minutes to notice. Even when a friend is waving to you from across a street, light must travel that certain distance from their hand to your eyes. In this respect, it could be said that the only thing humans are ever able to observe is the past. The Inspiration for the Models The First: As I mentioned earlier, the grandfather paradox has long been an issue facing discussions of time travel. This has given rise to Stephen Hawking's Chronology Protection Conjecture. The CPC suggests that anyone traveling back in time would be prevented from any violation of causality. In other words, the CPC suggests that if you were to ever to go back in time in your past, you had already done so. Recall our metaphor of time as a river. In this metaphor, imagine a small stream that diverges off of the main river and circles back into the river at another point – in the language of time travel, this would be called a closed time-like curve. Under the CPC, if you were to go back in time and attempt to kill your grandfather, or yourself, or make any attempt to alter history as you knew it, you would fail. Perhaps you would slip on a conveniently placed banana peel at the last instant. But regardless of how you were foiled, anything you could have done to affect the outcome of things would already be part of your memory, because you had already lived through it. Causality Recall the CPC says causality is preserved. Causality, to put it in brief, is the notion that every effect has a cause and that the effect can never come first. More specifically, if A causes B, then it is necessary that A chronologically occurred first. This statement can be rephrased to if A happens before B, and if the two are causally linked, then A was the cause and B was the effect.10 As it turns out, causality is a way that many people and cultures have used to define what time is in itself. Time and history, this view suggests, is a domino effect of one cause creating an effect, which functions as the cause for another effect, and so forth, and so forth. 10 Nahin 185 – 191. The Second: The inspiration for the second model comes from resolving the grandfather paradox via the conservation of matter (or more specifically, mass and energy). Antoine Lavoisier (1743 – 1794) was a pioneer of a scientist in being the first to show that the total mass of any closed system is conserved, meaning that the amount of matter within a system always stayed the same. Many stories about time travel like to invoke the grandfather paradox and suggest that preventing your birth would make you slowly disappear from existence.11 Here is where I will invoke conservation of matter, the law of physics which says matter can neither be created nor destroyed. Even in a world where one is assuming that time travel is possible, it is impossible to violate one of the most basic laws of physics that governs our existence – assuming, that is, that you have not entered a new universe governed by seemingly new laws. It can be seen, therefore, that this model, as well as the first one, will be restricted to one time, or one worldline. I will show, then, how the second model assumes that time functions in the same basic way as the first, but that in the second, the CPC does not hold. The Third: The third model is inspired by the physics and philosophy that come from modern research in quantum mechanics. In QM, sometimes a radioactive source decays, and sometimes it does not. What the physicist has to do, then, is assume that the system is in a superposition of both possible states.12 This leads to the notion that there are parallel universes – one in which the radioactive source decays and one where it does not. In fact, this can be extended to every 11 Two notable examples of this in film include Back to the Future (1985) and Looper (2012). 12 The famous example of this is Schrödinger's Cat. If a radioactive source decays in a box, then a mechanism releases that kills a cat trapped within a box. But, if the source does not decay, the cat is fine. Since the scientist cannot know whether or not the cat is alive or dead before opening the box, the cat is assumed to be a superposition of both states. decision that you make every day an alternate universe where you made a different choice. can be thought of as "copies" of each other, As shall be seen in the descriptions of the models, the third model contains the possibility of parallel worldlines that would not be able to interact with each other. does not require that the universe A Note on One Timeline versus Parallel Times The first two models restrict the universe to one timeline restricted to one existence that contains a given point in the world. This is an important distinction to make because parallel universes, and therefore parallel "copies" of oneself have a tendency to make people rethink what "the self" means to them, often t comfortable to mankind's self-identity purposes of this discussion, though, we will consider both situations a either assumption – the situations in which time is restricted to one timeline and when it is not. Models of Time Linearly Fixed Time As previously mentioned, this first model follows in line with the Chronology cision that you make every day, i.e. for every decision you have ever made, there could an alternate universe where you made a different choice. These parallel universes, although "copies" of each other, are not able to physically interact with one another. As shall be seen in the descriptions of the models, the third model contains the possibility of s that would not be able to interact with each other. This model, obviously, the universe passes only through one distinct timeline. A Note on One Timeline versus Parallel Times The first two models restrict the universe to one timeline. Specifically that means that they are to one existence that contains a past, a future, and a present for any observer at any This is an important distinction to make because the possibilities of parallel universes, and therefore parallel "copies" of oneself have a tendency to make people to them, often to uncomfortable ends. As a result, it identity to believe that there could only be one existence. For the purposes of this discussion, though, we will consider both situations and see what derives from the situations in which time is restricted to one timeline and when it is not. As previously mentioned, this first model follows in line with the Chronology Figure 3 for every decision you have ever made, there could exist These parallel universes, although they are not able to physically interact with one another. As shall be seen in the descriptions of the models, the third model contains the possibility of This model, obviously, . Specifically that means that they are observer at any the possibilities of parallel universes, and therefore parallel "copies" of oneself have a tendency to make people , it would be more to believe that there could only be one existence. For the nd see what derives from the situations in which time is restricted to one timeline and when it is not. 11 Mantica: Models of Time Published by DigitalCommons@Kennesaw State University, 2015 Protection Conjecture. In this model, all points of time are fixed with respect to each other and are moving in line with one another. A big assumption here, as we have discussed, is that there is one and only one timeline that can exist for the universe. Again, since we are assuming that the CPC holds, if this is how time functions, this would mean that any trip into the past you went on would have been something you have always done. Consider Figure 3. Trace your finger from the left side of the diagram to the right, and follow the closed loop on your path. This is a representation of how traveling backward in time would work in this model. As an example, let us say that you are a scientist with a time travel machine in your laboratory, and you make the decision to send a cup of coffee to yourself in the past. "In one hour," you say, "I will send myself a cup of coffee to this very moment." Then, suddenly before your eyes a cup of coffee appears! After you enjoy the hot cup of joe, an hour later, you brew a new cup and send it back to your past self. Now, here you might notice we have a sort of reverse grandfather paradox. What if in one hour's time, you make the decision to not send the cup of coffee? According to the tenets of the chronology protection conjecture, you would be physically bound by laws of causality of the universe to send that cup of coffee (so much for free will). Notice though that causality is saved, albeit circularly, in this model. Issues with Linearly Fixed Time But what if you then did not have to send the coffee back after having received it? This issue will be resolved by the second model. This model, rather, would also suggest that if anyone had ever traveled back in time to our past, we would already know about it. The "Where are all the time travelers?" argument has been made before and addressed many different ways. Perhaps the strongest answers, however, involve the limits on proposed time machines – recall the description of wormhole travel earlier, that might only be able to travel back to one specific point. In a sense, then, this model is the simplest model because the universe is restricted to one worldline, and any trip to the past would be just as much a part of your past as it would be a part of your present and future. Linearly Mutable Time Let us now say you receive that cup of coffee, but then make the conscious decision to not send the cup back to yourself. Restricting the universe to only one timeline, this would imply that you are rewriting time as had been previously experienced. Think as in Figure 2, but altered by changing something about the past, i.e. coffee cup, or killing your grandfather, y rewrite history (this is represented by the grey arrow along the timeline). In this view, preventing one's birth does not mean that you suddenly cease to exist, but that you will live through a newly-formed timeline in which you are never born. assuming that there can exist only one is given the title "linearly mutable. Figure 4 ion of wormhole travel earlier, that might only be able to travel back to one specific In a sense, then, this model is the simplest model because the universe is restricted to one rldline, and any trip to the past would be just as much a part of your past as it would be a part Let us now say you receive that cup of coffee, but then make the conscious decision to not send Restricting the universe to only one timeline, this would imply that you are rewriting time as had been previously experienced. Think of time as having occurred exactly by changing something about the past, i.e. by deciding not to send the coffee cup, or killing your grandfather, you change the past as you knew it. See Figure 4 traveler's journey first goes along the black arrow, and then the grey. Also notice in the figure that after making a change in time, one would, in effect, rewrite history (this is represented by the grey arrow along the timeline). In this view, preventing one's birth does not mean that you suddenly cease to exist, but that you formed timeline in which you are never born. Since this assuming that there can exist only one distinct timeline at any given instant, but it is alterable, it linearly mutable." ion of wormhole travel earlier, that might only be able to travel back to one specific In a sense, then, this model is the simplest model because the universe is restricted to one rldline, and any trip to the past would be just as much a part of your past as it would be a part Let us now say you receive that cup of coffee, but then make the conscious decision to not send Restricting the universe to only one timeline, this would imply that you of time as having occurred exactly deciding not to send the . See Figure 4, where a t goes along the black arrow, and then the grey. otice in the figure that after making a change in time, one would, in effect, In this view, preventing one's birth does not mean that you suddenly cease to exist, but that you this model is en instant, but it is alterable, it As a further example, consider now two time travelers, A and B. A goes back in time and prevents the birth of B through some nefarious spy-versus-spy hijinks. A year passes and B makes the decision to go back in time and witness his turning six-months-old. When he arrives, he can find no trace of his existence! Issues with Linearly Mutable Time This model also brings up another unsettling question. This time around, let us start at the assumption that the timeline that we currently live in and experience has been untouched by time travelers. Then, an audacious time traveler decides to go back in time and assassinate Adolf Hitler with the idea that this would prevent many atrocities of the Second

World War.13 This, obviously, changes history as we knew it in a dramatic way. But then would a time traveler from that changed timeline, who decided to travel into the distant future, see his or her changed history's future or our history as we know it today? To settle this question, recall how I have defined forward time travel in the section headed "Words of Warning." Pending discussion on the nature of the method (or the machine) that is doing the travelling, I am considering forward time travel to constitute removing oneself from time, letting that time continue on, and placing yourself back in at a later point. With this in mind, an observer not doing the traveling would see the traveler leave, live through that certain amount of time, and then see the traveler arrive back at a later point. Again, I will discuss what the traveler experiences during this interval later, I promise. But it can be seen by this example that instantaneous travel to the future could create logical problems with alternate futures in one 13 Killing Hitler seems to be a commonly used example when discussing going back in time and changing the past. Most likely because his existence was such an integral part of the Second World War, but it is curious nonetheless. For more information, see Inglis-Arkell, Ester. "Are We Running out of Time to Kill Hitler via Time Travel?" Io9. August 6, 2012. Accessed April 1, 2015. http://io9.com/5932026/are-we-running-out-of-time-to-killhitler-via-time-travel. 14 timeline. Imagine that, in this model of time, our observer Hitler, and then using his or her "travel instantaneously to the future" machine, jumps forward to the point in time that he or she originally left. In this scenario, the traveler would not see a history in which Hitler had been killed, but i time had not yet been rewritten. B has prevented it? Multilinear Time The issue of time traveler B not being time. That is to say, any change in the past would create an intangible and parallel timeline to the line the traveler left, as seen in Figure 5 This would mean that if traveler A went back in time and prevented the birth of B, and thusly created a separate timeline, that B would However, if B traveled to a point before A ever attempted to prevent B's birth, B would then be able to see A's attempt and maybe even stop him. This would, then, create y divergence. Consequently, the implication of this flows along the most recently diverted path. Figure 5 Imagine that, in this model of time, our observer does go back in time and assassinate "travel instantaneously to the future" machine, jumps forward to originally left. In this scenario, the traveler would not see a had been killed, but instead history as had he or she knew . But can we reconcile B's inability to view his own past The issue of time traveler B not being able to travel into the past as he knew it can be assuaged if we do not restrict the universe one distinct timeline. quantum mechanics, metaphor of the river, chance that changing the past creates a divergence in the time. That is to say, any change in the past would create an intangible and parallel timeline to the aveler left, as seen in Figure 5. This would mean that if traveler A went back in time and prevented the birth of B, and thusly d a separate timeline, that B would still be able to go back and visit his own past. However, if B traveled to a point before A ever attempted to prevent B's birth, B would then be able to see A's attempt and maybe even stop him. This would, then, create yet another the implication of this is that to an observer going through time, time flows along the most recently diverted path. 5 does go back in time and assassinate "travel instantaneously to the future" machine, jumps forward to originally left. In this scenario, the traveler would not see a had he or she knew it because that ut can we reconcile B's inability to view his own past after A able to travel into the past as he knew it can be assuaged if the universe to one distinct timeline. In the vein of quantum mechanics, and our metaphor of the river, consider the that changing the past creates a divergence in the river of time. That is to say, any change in the past would create an intangible and parallel timeline to the This would mean that if traveler A went back in time and prevented the birth of B, and thusly be able to go back and visit his own past. However, if B traveled to a point before A ever attempted to prevent B's birth, B would then be et another is that to an observer going through time, time 15 Mantica: Models of Time Published by DigitalCommons@Kennesaw State University, 2015 There is a key thing to point out about traveling through time under this model: traveling into the past and changing time as you experienced it, means that you could never return to the timeline you left. Keeping the scenario of travelers A and B in mind, let us say that after A has prevented the birth of B, A decided that the prank was well-done and wants to have a good laugh with B about it. But under this model, B has created an alternate reality in which A will never be born, and any attempts A makes at going to the future or the past will not result in being able to see B ever again. A helpful way to picture this, is that of a dam that diverts the direction of a river. This way, anyone traveling from a point in the past travels along the most recently diverted path. It is in this model that discussions of the quantization of time and the nature of the machine are most important. Because, if time is indeed quantized, then that means that there is a specific instant to which one could travel to in order to make a change, and that two travelers could each travel to the same exact moment in time. What is more, that also means that there is a distinct moment before and a moment after a time in which any change is made where beforehand a traveler could witness history as he knew it, and in the moment after he would witness a new history following the changed moment. Issues with Multilinear Time Perhaps the biggest issue facing the model of multilinear time is that if time is able to separate into two timelines, can two timelines join into one? I say no, because more parallel universes in existence means more entropy, or a decrease in predictability of order, and the second law of 16 Oglethorpe Journal of Undergraduate Research, Vol. 5 [2015], Iss. 2, Art. 1 https://digitalcommons.kennesaw.edu/ojur/vol5/iss2/1 thermodynamics says that all closed systems must increase in entropy over time. In fact, many physicists use this as a definition of time and as part of proof that time is linear.14 A further response to this is that there is already something in nature that is observed to naturally split and not to naturally come together: nuclear decay in radioactive materials. Radioactive materials lose nucleons (through release of other particles) naturally, while nuclear fusion, or the coming together of nucleons, only occurs naturally in the universe in stars – and in those situations, the star can be thought of as a furnace that is doing work in order to achieve that fusion – but it has never been observed to occur unprompted on Earth. 14 Cramer, "On Time Travel." 17 Mantica: Models of Time Published by DigitalCommons@Kennesaw State University, 2015 Corollaries to Multilinear Time Is Time Quantized Planck Time is defined by physicists to be the amount of time it takes for light to cross a distance (called a Planck Length) that is determined by Plan exchange of energy possible. In simpler words, Plan can pass between two events and it is calculated to be 5.39 x not mean that time moves forward in distinct increments. The chronon was first proposed in 1927 by Robert Lévi, but a theoretical value for it was not suggested until 1997 in the paper " Quantum Mechanics" by Ruy A. H. Farias and argue that the length of a quantized amount of time for a given system is as follows: Modern research into whether or not time moves in distinct increments been experimentally determined, and there are possible experiments or any discoveries on the topic. This may a seamless continuum. On the other hand, Plank's Constant, the smallest unit of energy exchange possible, can be experimentally determined many different ways (many of physics labs). This quantization of energy per second, and subsequent quantization of length, Corollaries to Multilinear Time k Time is defined by physicists to be the amount of time it takes for light to cross a k Length) that is determined by Planck's Constant, or the smallest exchange of energy possible. In simpler words, Planck Time is the minimum amount of time that can pass between two events and it is calculated to be 5.39 x 10-44 seconds. This, however, does not mean that time moves forward in distinct increments. The chronon was first proposed in 1927 by Robert Lévi, but a theoretical value for it was not suggested until 1997 in the paper “Introduction of a Quantum of Time, and its Consequences for ” by Ruy A. H. Farias and Erasmo Recami. In this paper, Farias and Recami argue that the length of a quantized amount of time for a given system is as follows: Modern research into whether or not time moves in distinct increments, i.e. chronons, been experimentally determined, and there are unfortunately few scientists who have published possible experiments or any discoveries on the topic. This may imply, rather, that time moves in On the other hand, Plank’s Constant, the smallest unit of energy exchange possible, can be experimentally determined many different ways (many of which are done in undergraduate uantization of energy per second, and subsequent quantization of length, k Time is defined by physicists to be the amount of time it takes for light to cross a specific k’s Constant, or the smallest k Time is the minimum amount of time that seconds. This, however, does The chronon was first proposed in 1927 by Robert Lévi, but a theoretical value for it was not and its Consequences for In this paper, Farias and Recami argue that the length of a quantized amount of time for a given system is as follows: (Equation 1) , i.e. chronons, has not yet few scientists who have published that time moves in On the other hand, Plank’s Constant, the smallest unit of energy exchange possible, can be are done in undergraduate uantization of energy per second, and subsequent quantization of length, 18 Oglethorpe Journal of Undergraduate Research, Vol. 5 [2015], Iss. 2, Art. 1 https://digitalcommons.kennesaw.edu/ojur/vol5/iss2/1 may indeed imply that time can be quantized as w will be true. Nature of the Method A quick way to undermine the model of Multilinear T new parallel universe, where does all of that new matter come from?” the method of traveling becomes important. If the method of time travel into the past involves a wormhole, we have two possibilities: A.) Rather than connect two points identical yet parallel universes B.) Via the nature of wormholes, rather than connect two points in space points in time in the same universe. If A.) were true, then traveling through time would affect the timeline of the universe much in the way of the Linearly Mutable model, but from the traveler’s perspective the universe would seem to function under the Multilinear model. Here, we have no worry about creating new matter, because this suggests that there are indistinguishable parallel universes full of the same matter in ours that are connected by the wormhole in question. If B.) were true, then this gives rise to what are called temporal loops like what is represented in Figure 3 may indeed imply that time can be quantized as well. Only the future can tell which of the two A quick way to undermine the model of Multilinear Time might be to say, “In order to create this new parallel universe, where does all of that new matter come from?” This is where the nature of the method of traveling becomes important. If the method of time travel into the past involves a e two possibilities: Rather than connect two points in space of the same universe, wormholes connect two identical yet parallel universes (perhaps leading to different places or times) Via the nature of wormholes, rather than connect two points in space, they connect two points in time in the same universe. If A.) were true, then traveling through time would affect the timeline of the universe much in the way of the Linearly Mutable model, but from the traveler’s perspective the universe would seem to function under the Multilinear model. ry about creating new matter, because this suggests that there are indistinguishable parallel universes full of the same matter in ours that are connected by the wormhole in question. rise to what are called temporal loops. A temporal loop, much what is represented in Figure 3, often requires that the traveler experience the amount of Figure 6 which of the two ime might be to say, “In order to create this This is where the nature of the method of traveling becomes important. If the method of time travel into the past involves a of the same universe, wormholes connect two (perhaps leading to different places or times). , they connect two If A.) were true, then traveling through time would affect the timeline of the universe much in A temporal loop, much often requires that the traveler experience the amount of 19 Mantica: Models of Time Published by DigitalCommons@Kennesaw State University, 2015 time that they are traveling back.15 Once the traveler arrives in the past, by changing it, he creates a new timeline using all of the matter that was already existing at that point in the universe and the matter that made up the previous timeline continues existing on its own. See Figure 6. A Note on Holes to Specific Points As we briefly addressed earlier, there is a possibility that we have never seen time travelers before because wormholes connect two specific points of time and space. If we assume, then, that one day scientists will be able to build and/or control a wormhole, that means that the one end of the hole that the scientists have created is fixed either to that place or that time. A time machine like this would only be able to go so far back in time as to the date that it was created.16 On Changing the Past Postulate: Assuming chronology protection is false, any trip to the past changes history as understood from the timeline you left. The reader may be curious as to what events constitute a change in history and what do not. If a time traveler went back in time and sat in a cave for the rest of his life, would that create a divergence in the timeline or rewrite history? Yes. Simply by nature of the matter that makes up the traveler's body, there is a displaced volume of particles that had to go somewhere else in the universe, as well as effects from your body's gravitational field that had not previously been there. Because of this, under the assumption that chronology protection is false, a time traveler's mere existence in the past would change history as he previously knew it. Experiments to Lend Credibility or Discredit the Models 15 For an excellent example of this in film, see Primer (2004). 16 This is argued for in detail by Thorne, Kip. Black Holes and Time Warps, 501 - 505. New York, New York: W. W. Norton & Company, 1994. 20 Oglethorpe Journal of Undergraduate Research, Vol. 5 [2015], Iss. 2, Art. 1 https://digitalcommons.kennesaw.edu/ojur/vol5/iss2/1 The Experiments Let us now assume that a friend has brought you a device which he claims is a time machine. Provided below then is a list of ideas for some experiments to carry out, in descending order, which will serve as evidence for or against these models. 1.) Make the conscious decision to send yourself something, and carry that decision out. Recall our example of sending yourself back in time a cup of coffee.17 If you make the decision to send yourself back a cup of coffee, and then suddenly a cup of coffee appears, this is strong evidence that time behaves linearly fixed. On the flipside, if nothing appears before you and then you send yourself back the cup of coffee and you never see it again, this is evidence that suggests time behaves in another model. Note that this is assuming that the time machine actually works and that you did not just obliterate a perfectly good cup of coffee. 2.) Make the conscious decision to send yourself something, and do not carry that decision out. One of two things will then happen. If no cup of coffee appears before you in this case, we still have the possibility that the linearly fixed model (or really any model for that matter) holds true. However, if a cup of coffee does appear before you and you make the decision to not send yourself the cup following that, we have evidence to suggest that our decisions can alter the past – lending credibility to either the linearly mutable or multilinear models. 17 While a clock, or a stopwatch, might be the more scientific and logically-sound object to send, the author is incredibly grateful to coffee (without which many of these ideas would not have come to fruition) for getting him through most of his life. So we shall continue with the example of cups of coffee. 21 Mantica: Models of Time Published by DigitalCommons@Kennesaw State University, 2015 3.) Send an object to yourself yesterday, and after one day has passed, send yourself (or an observer) into the past half of a day to check on the object. First note that the time scale of a day and a half-day are arbitrary. What is important for this test is that the length of time that you sent the object passes and you then send yourself (or an observer) to a time longer ago than that. Obviously, if a day ago you received the package, then time is likely linearly fixed. But if time is not linearly fixed, and to you the object was distinctly not part of the past in your life as you knew it, there are two possibilities. If you travel into your past and see the object, this is evidence to suggest that time is linearly mutable, i.e. you rewrote your past when you sent an object back in time, and you are now rewriting history. Conversely, if you go into your past and can find no record of the object, this is evidence to suggest that time behaves multilinearly and that you created a divergence in time when you sent the object back, but still have the freedom to visit the past in your own timeline as you knew it. Example of Experiment 3 Imagine that we have determined that the universe in which we live is not linearly fixed. Let us then send back in time the gift of a puppy on the day you were born. For the purposes of the example, we will assume that you and the puppy grow up as best friends. After a year passes, we will go back to when you were six months old and see how you and the puppy are getting along. If you see six month year old you playing with the beloved puppy, then this suggests that time is linear and mutable. Conversely, if you were to find the six month old you exactly as you remembered having lived through, and no record of the puppy at all, this would suggest that time is multilinear. Should This Be Considered Science? I would loosely define science as anything that follows what is known as the scientific method. That is, anything that consists of testable predictions of hypotheses that are made based on observations of the universe. While we do not currently have the ability to send objects, let alone people, through time, I would say that these are hypotheses that although are not yet testable, hopefully one day they will be. I have done my best to keep these hypotheses scientific, though. After all, claiming that time moves from past to the future is entirely based on observation. So all in all, while under my definition these claims are not wholly scientific, I have followed what parts of the scientific method that I can and I hope one day study of time travel will be fully considered a science. Is there Modern Research on Time Travel? The answer to that question is yes, but very little. Since there are few experiments that can be carried out, there is little research published on actual time travel. Some experiments have attempted to prove or disprove causality, but little progress has been made in any direction. Perhaps the most perplexing experiment that may violate causality is what physicists call "action at a distance." In what is known as the EPR experiment, two particles are sent off in two directions, but a measurement on one particle affects the second particle even when they are incredibly far apart. While there is certainly something happening in this situation that physicists do not currently understand, one accepted explanation is that there are not-yet-understood superluminal forces acting on the two.18 The Possibilities of Time Travel If a solid proof that time travel is impossible comes along, then I suppose I have provided the reader with a very thorough account of different ways time cannot function. But as we proceed into the future, more and more experiments on the nature of time will be performed. We previously discussed the idea of a wormhole that connects two points in time, which would mean that time machines would only be able to go back to the point in space and time at which they were created, but what about other possibilities? Briefly mentioned in the discussion on the Tipler Cylinder, many physicists believe that the most possible method of traveling through time would be using an incredibly dense material around a traveler. In Einstein's relative universe, masses have the ability to warp space (and therefore time) around them. Thus, an incredibly dense material – denser than any material currently known – might be able to be used to warp space-time so drastically that it can loop around a traveler. I remain hopeful that one day experiments on the nature of time and new ways of traveling through it will come to full realization. Travel through time has, however, captivated the minds of humans ever since we understood the concept of past, present, and future. And I believe that it will carry us into a future of even greater understanding.