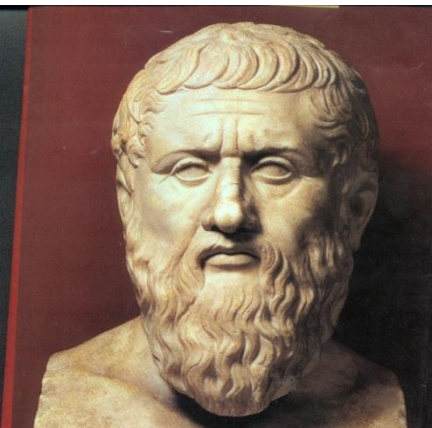
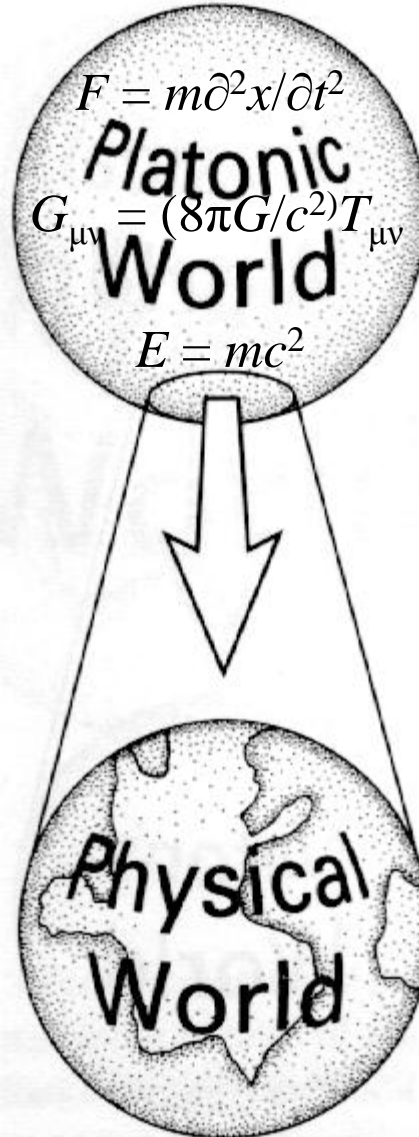




The nature of physical law

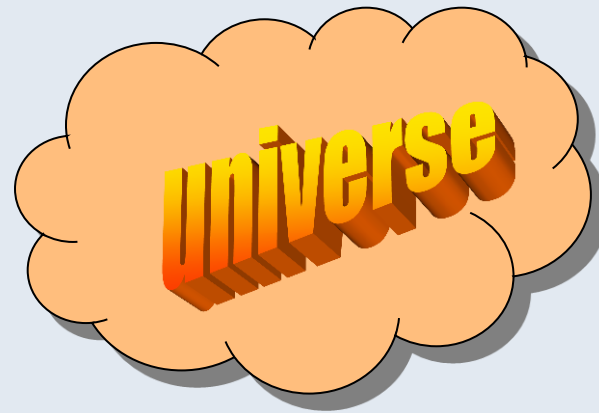


Bust of Plato

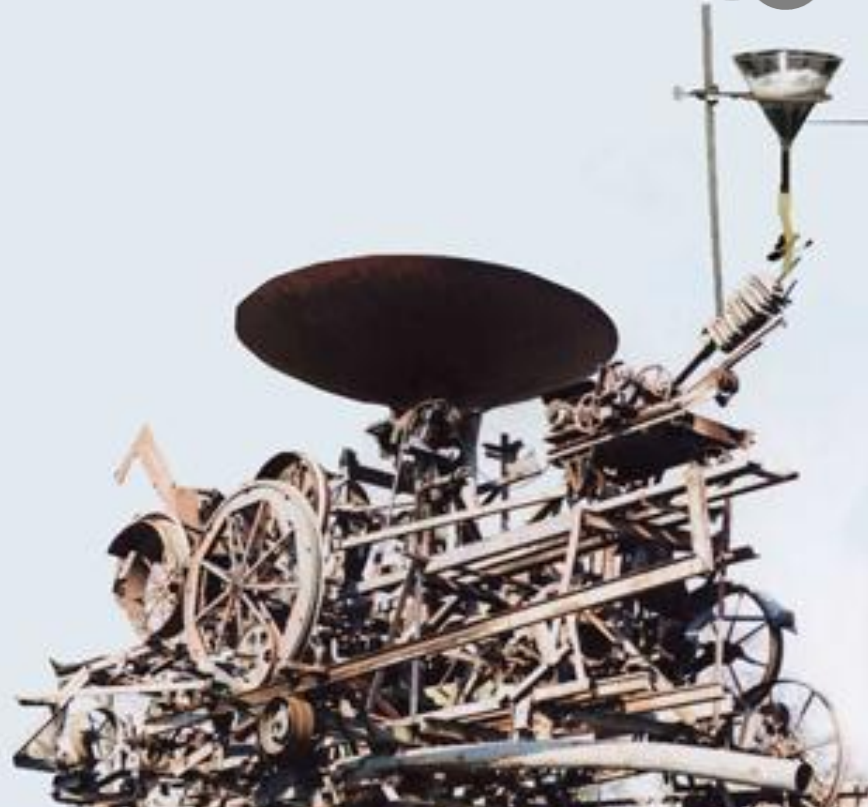
physics

mathematics

Universe generating mechanism



puff



Life and mind



The universe, matter



Laws of physics

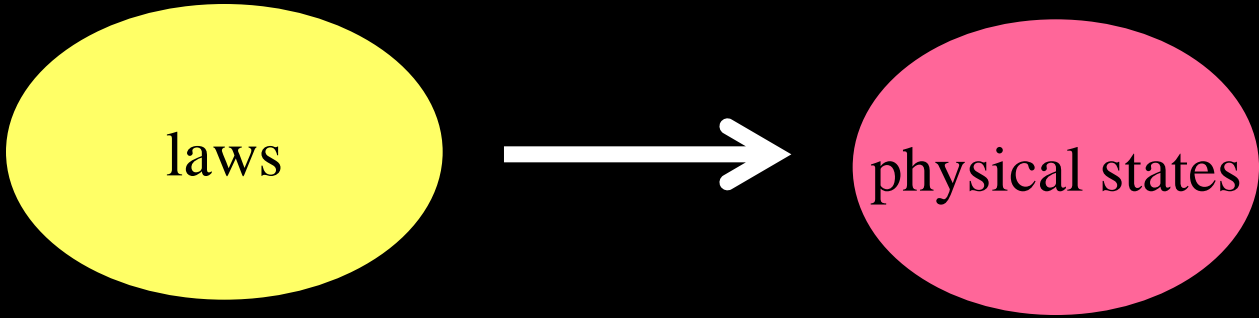


Mathematics



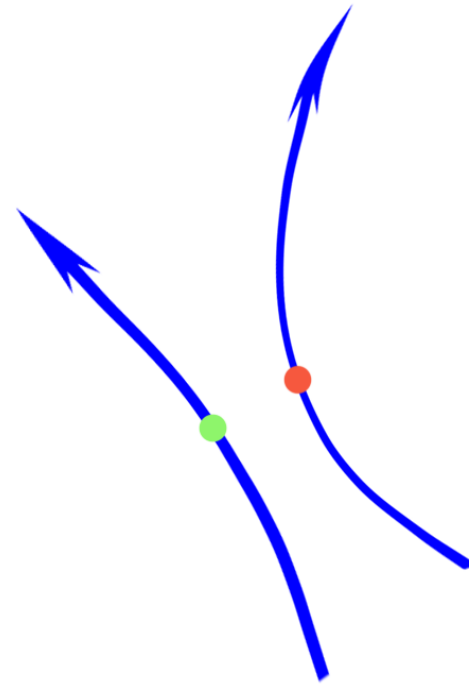
Laws are...

- Absolute
- Universal
- Timeless, immutable
- Perfect, infinitely precise, mathematical relationships
- Independent of states of the world

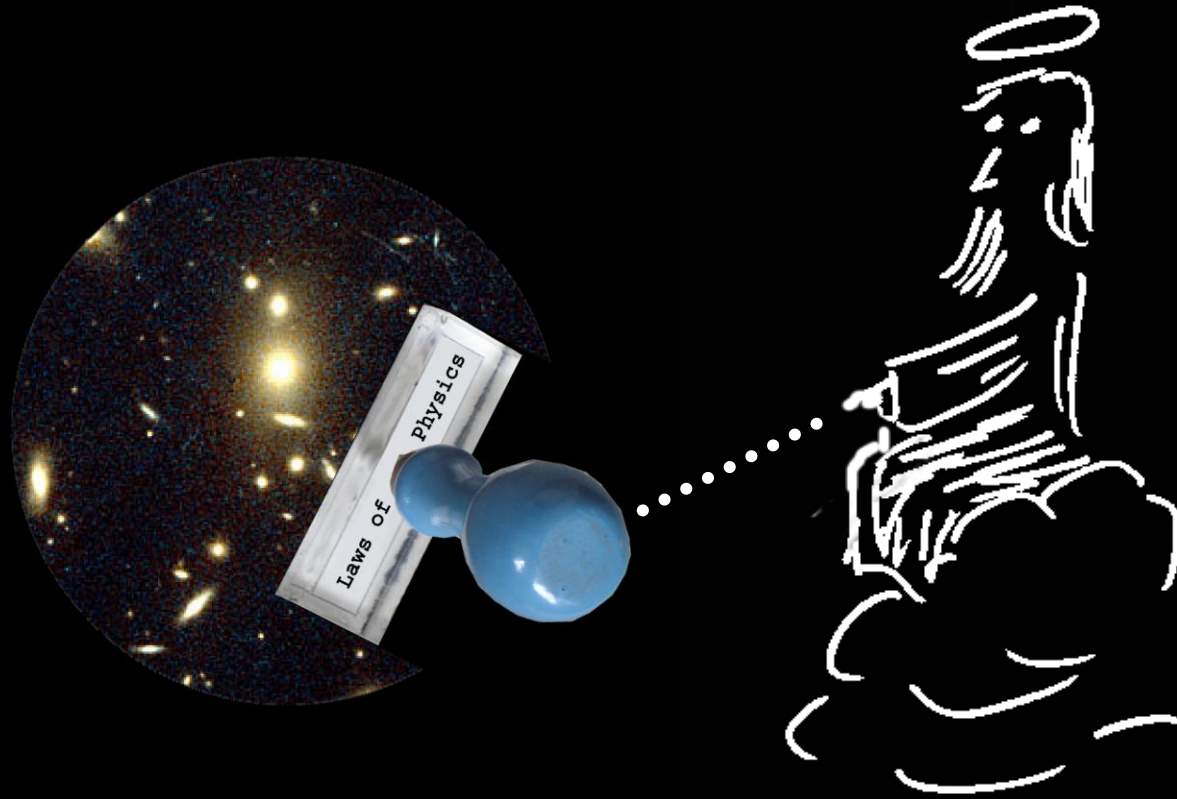




Pierre Laplace



“An intellect which at any given moment knew all of the forces that animate nature and the mutual positions of the beings that compose it, if this intellect were vast enough to submit the data to analysis, could condense into a single formula the movement of the greatest bodies of the universe and that of the lightest atom; for such an intellect nothing could be uncertain and the future just like the past would be present before its eyes.”



The laws are imprinted on the universe at the moment of its birth

Central claim

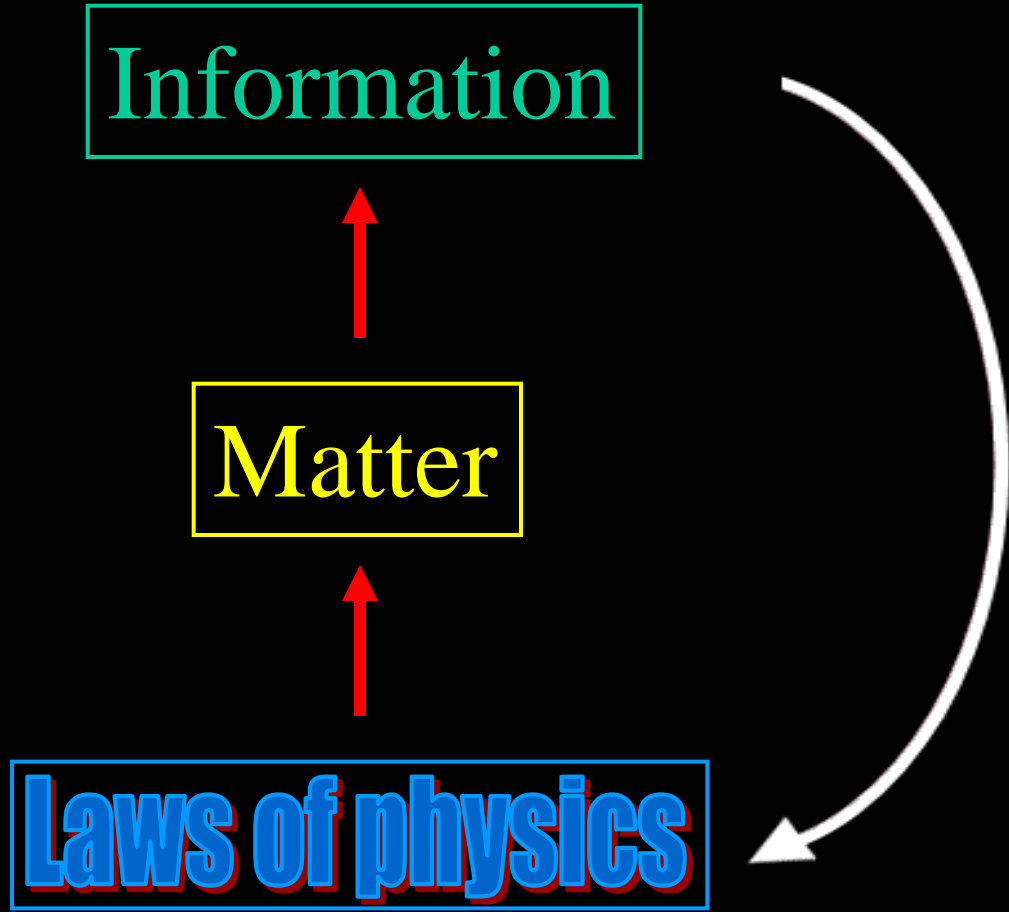
- The concept of an externally imposed set of infinitely-precise transcendent immutable time-symmetric mathematical relationships (“laws of physics”), together with their attendant mathematical entities such as real numbers, is an idealization with no justification in science, and represents an act of faith that is a hangover from European medieval theology and Platonic philosophy.



“It from bit”

We investigate nature via discrete yes-no acts of interrogation, and deduce physical laws as an idealized thread connecting the resulting informational bits, so...

Laws are informational patterns





“The laws we discover about nature do not already exist as ‘Laws of Nature’ in the outside world.”

Anton Zeilinger



Wheeler's law:

“There is no law except the law that there is no law”

The appearance of law emerges ‘from higgledy-piggledy...’



Universe as computer: laws as software



John Wheeler



Seth Lloyd



David Deutsch



Ed Fredkin



Stephen Wolfram



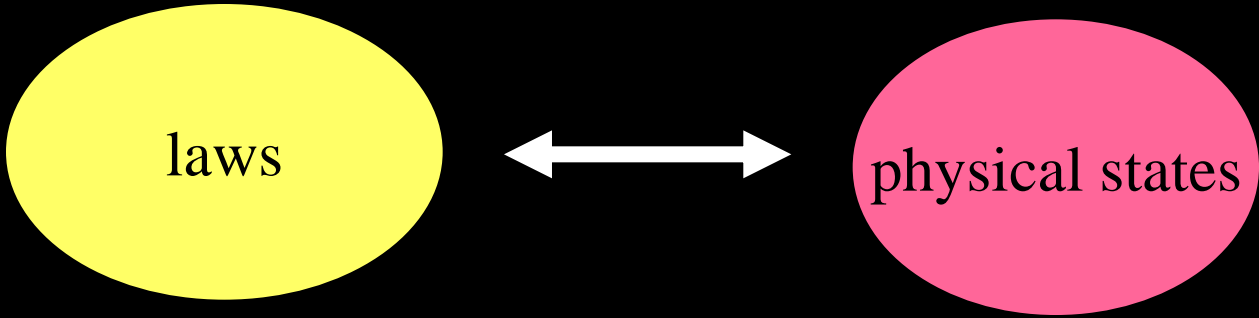
Rolf Landauer

Information is physical!

“The calculative process, just like the measurement process, is subject to some limitations. A sensible theory of physics must respect these limitations, *and should not invoke calculative routines that in fact cannot be carried out.*”

Self-consistent loop

- The laws tell nature how to compute
- Computation tells nature how to legislate





Information bound is time dependent

$$I \propto t^2$$

Seth Lloyd

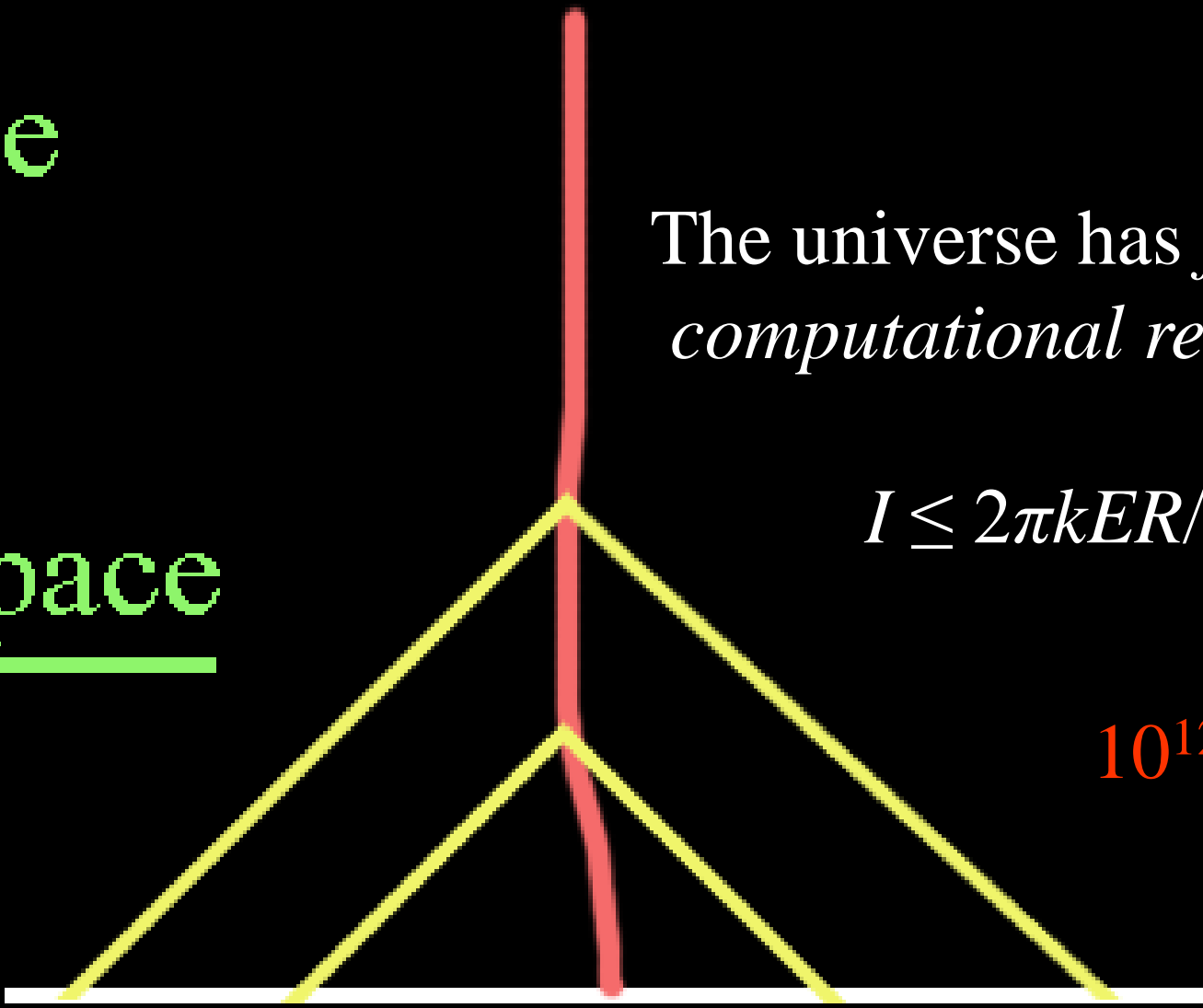
**10^{122} bits
today**

time
space

The universe has *finite*
computational resources

$$I \leq 2\pi kER/\hbar c$$

10^{122} bits



~~Macroscopic Poincaré fluctuations~~

~~Boltzmann brains~~

Truncating the quantum vacuum

$$\rho = \frac{1}{2} \hbar c L^{-1} \sum_{\underline{\mathbf{k}}} \omega \sim \omega^4, \omega \rightarrow \infty$$

$$\omega = \omega_P, \quad \rho \sim 10^{122} \rho_{\text{observed}}$$

$$\rho \sim \hbar c L^{-4} \sum n^4 10^{122}$$



Hubble radius

$$\rho \sim 10^9 \text{Jm}^{-3} \sim \rho_{\text{observed}}$$

$$\rho_{\text{observed}} \sim \sqrt{\rho_P \rho_H}$$

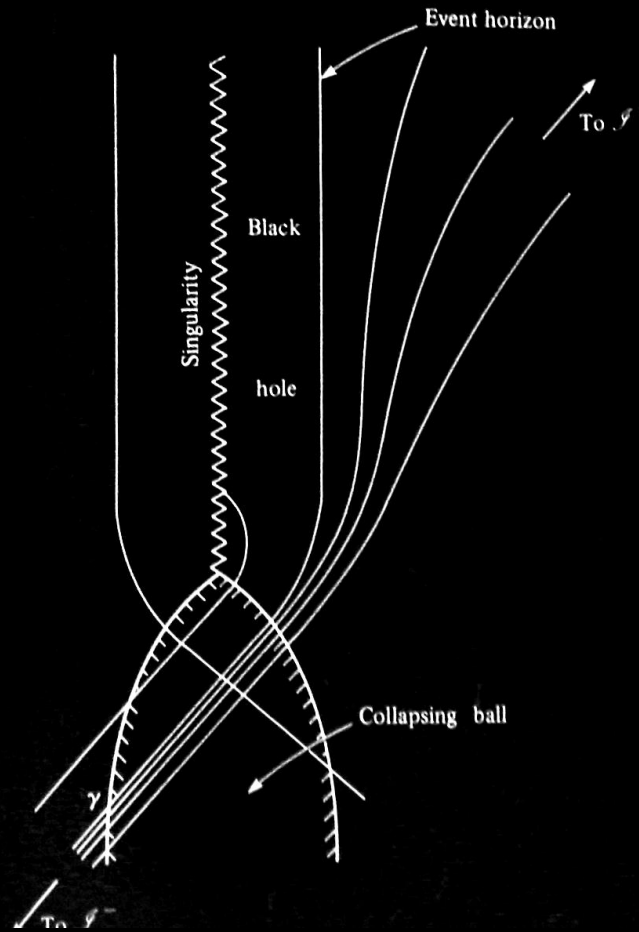
A possible experimental test!



n particles $\rightarrow 2^n$ possible states

$2^n \sim 10^{122} \rightarrow n \sim 400$ particles

The trans-Planckian mode problem



$$\exp(i\omega e^{u/4M})$$

$e^{3,000,000}$ after
1 minute!

$$\bar{u}_j = \sum_{i=0}^{\infty} (\alpha_{ji} u_i + \beta_{ji} u_i^*)$$



Seth Lloyd

Information bound is time dependent:

$$I \sim t^2$$

10^{122} bits
today

10^{20} bits at the
time of inflation

“This work is based on the idea that... [the] resources required to determine the properties of systems may influence what is true in physics and mathematics at a foundational level.” Paul Benioff

Resource Limited Theories and their Extensions

Paul Benioff

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(Dated: September 18, 2007)

This work is based on the idea that extension of physical and mathematical theories to include the amount of space, time, momentum, and energy resources required to determine properties of systems may influence what is true in physics and mathematics at a foundational level. Background material on the dependence of region or system sizes on both the resources required to study the regions or systems and the indirectness of the reality status of the systems, suggests that one associate to each amount, r , of resources a domain, D_r , a theory, T_r , and a language, L_r . D_r is limited in that all statements in D_r require at most r resources to verify or refute. T_r is limited in that any theorem of T_r must be provable using at most r resources. Also any theorem of T_r must be true in D_r . L_r is limited in that all expressions in L_r require at most r resources to create, display, and maintain. A partial ordering of the resources is used to describe minimal use of resources, a partial ordering of the T_r , and motion of an observer using resources to acquire knowledge. Reflection principles are used to push the effect of Gödel's incompleteness theorem on consistency up in the partial ordering. It is suggested that a coherent theory of physics and mathematics, or theory of everything, is a common extension of all the T_r .

PACS numbers: 02.10.Ab, 07.90.+c, 89.75.-k

I. INTRODUCTION

As is widely recognized, quantum mechanics and its generalizations, such as quantum field theory, is a highly successful theory. So far it has survived every experimental test. Yet in spite of this, nagging problems remain. The problem of measurement is one. Although the use of decoherence to solve the problem [1, 2] helps in that it explains the existence of the pointer basis in measuring apparatuses, questions still remain [3] that are related to whether quantum mechanics is really a theory of open systems only or whether there is a system such as the universe that can be considered to be closed and isolated. This is the approach taken by the Everett Wheeler interpretation [4, 5].

There are other more fundamental questions such as, why space-time is 3+1 dimensional, why there are four fundamental forces with the observed strengths, what the reason is for the observed elementary particle mass spectrum, and why the big bang occurred. Another basic question relates to why quantum mechanics is the correct physical theory. There are papers in the literature that address some of these questions by attempting to show that if things were different then life could not have evolved or some physical catastrophe would happen [6, 7, 8, 9]. However these are all heuristic after-the-fact types of arguments and do not constitute proofs. The possibility of constructing a theory to explain these things, as a "Theory of Everything" or TOE, represents

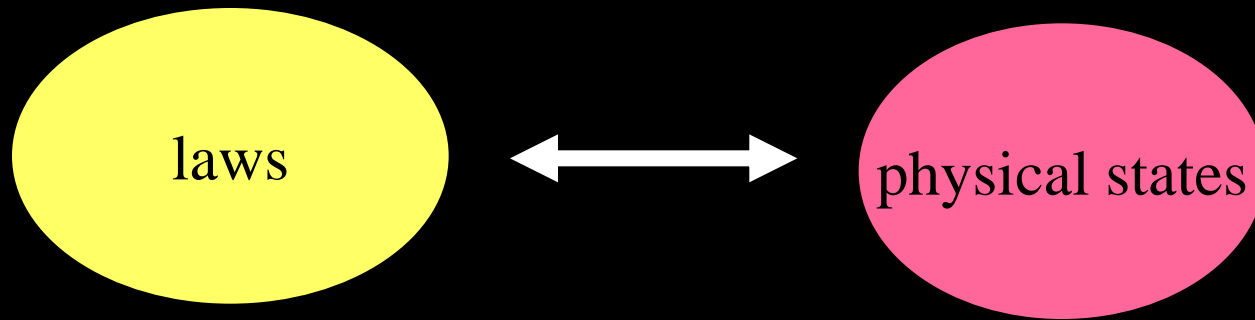
to an observers use of experiments to construct a theory of the physical universe. In particular it is felt that the properties of physical systems are independent of the basic properties of how an observer acquires knowledge and constructs a physical theory of the universe. This view is expressed by such phrases as "discovering the properties of nature" and regarding physics as "a voyage of discovery".

A similar situation exists in mathematics. Most mathematicians appear to implicitly accept the realist view. Mathematical objects have an independent, a priori existence independent of an observers knowledge of them [14, 15]. Progress in mathematics consists of discovering properties of these objects.

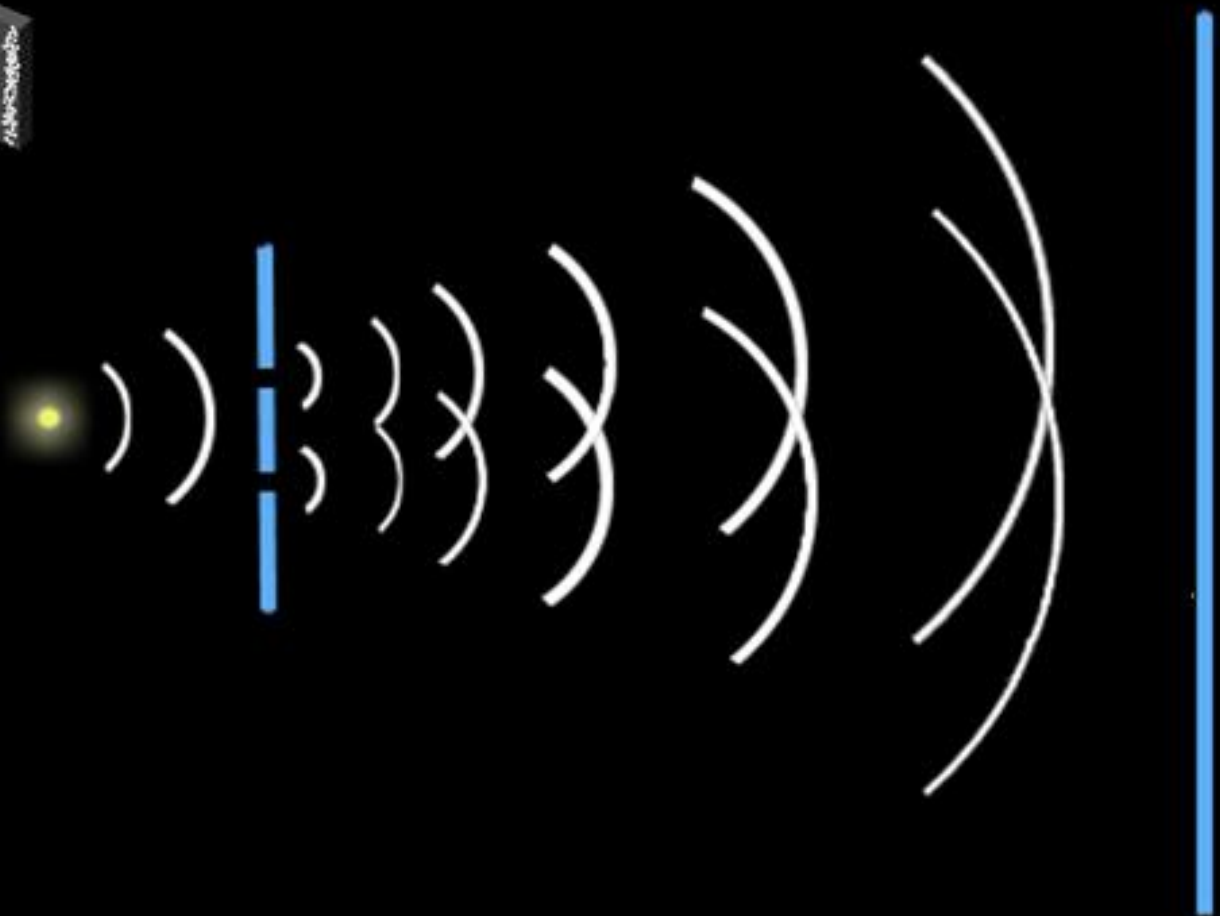
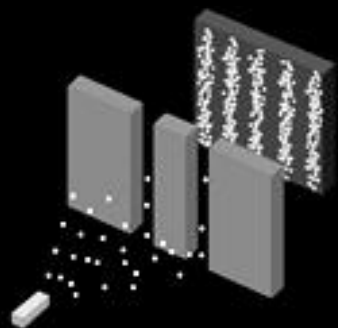
This is perhaps the majority view, but it is not the only view. Other concepts of existence include the formalist approach and various constructive approaches [16, 17, 18, 19]. These approaches will not be used here as they do not seem to take sufficient account of limitations imposed by physics. These include limitations resulting from the physical nature of language [20].

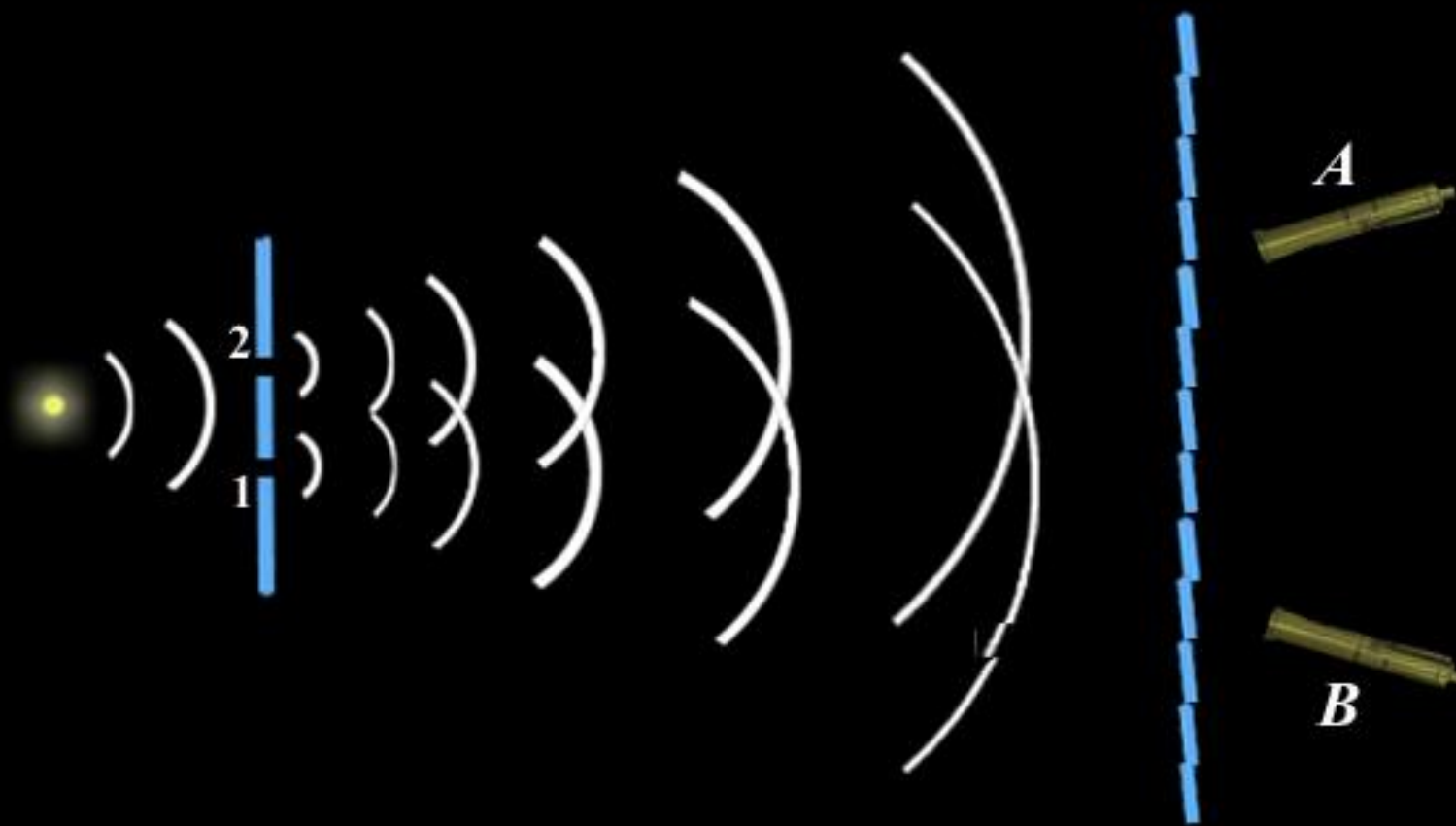
This realist view of physics and mathematics has some problems. This is especially the case for the widely accepted position that physical systems exist in and determine properties of a space-time framework. However, mathematical objects exist outside of space-time and have nothing to do with space-time. If this is the case, then why should mathematics be relevant or useful at all to physics? It is obvious that they are closely

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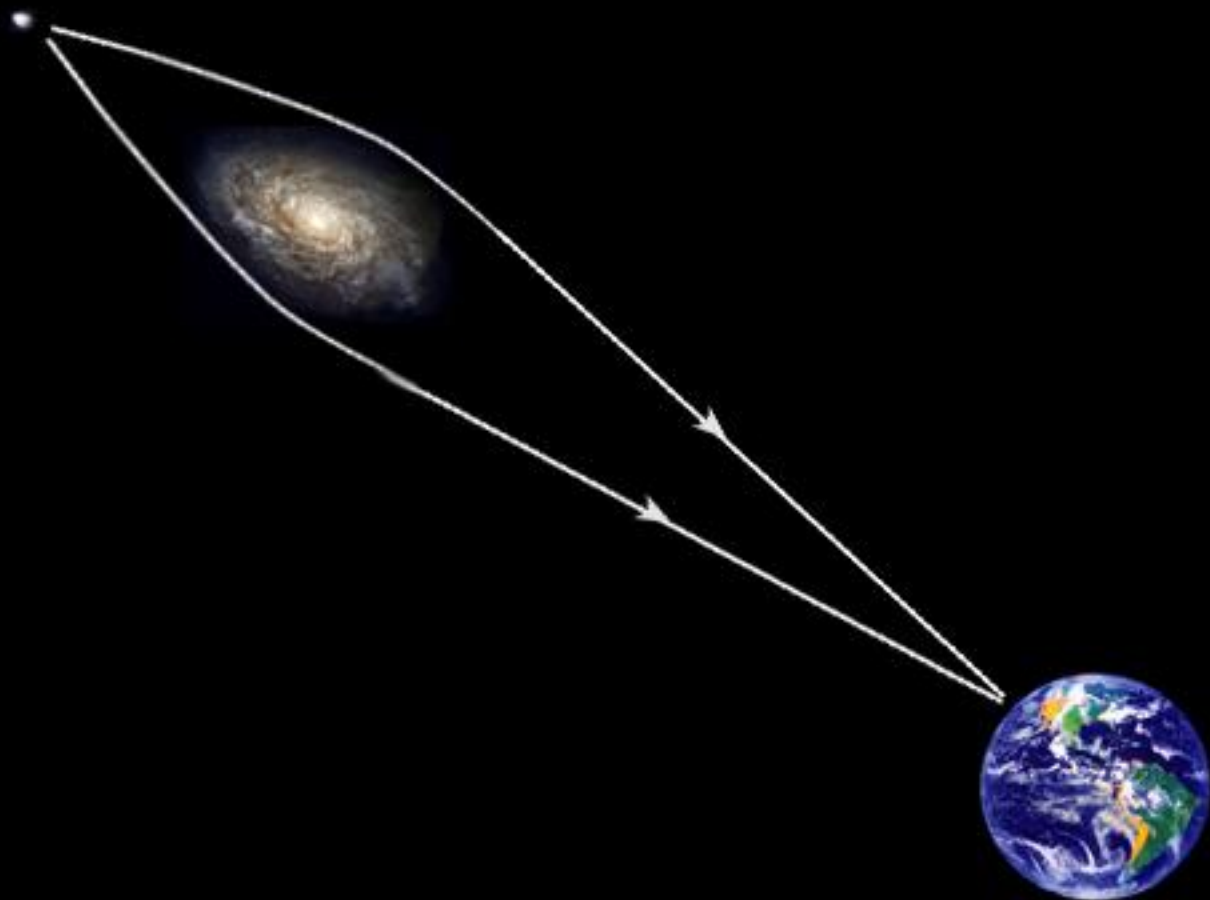


But... what is the feedback mechanism?





Wheeler's delayed-choice experiment



Hawking and Hertog

The top down approach we have described leads to a profoundly different view of cosmology, and the relation between cause and effect. Top down cosmology is a framework in which one essentially traces the histories backwards, from a spacelike surface at the present time. The no boundary histories of the universe thus depend on what is being observed, contrary to the usual idea that the universe has a unique, observer independent history.

“It is feasible and even suggestive to consider an extension of quantum mechanics to include both a wavefunction arriving from the past and a second ‘destiny’ wavefunction coming from the future.”



matter



laws

