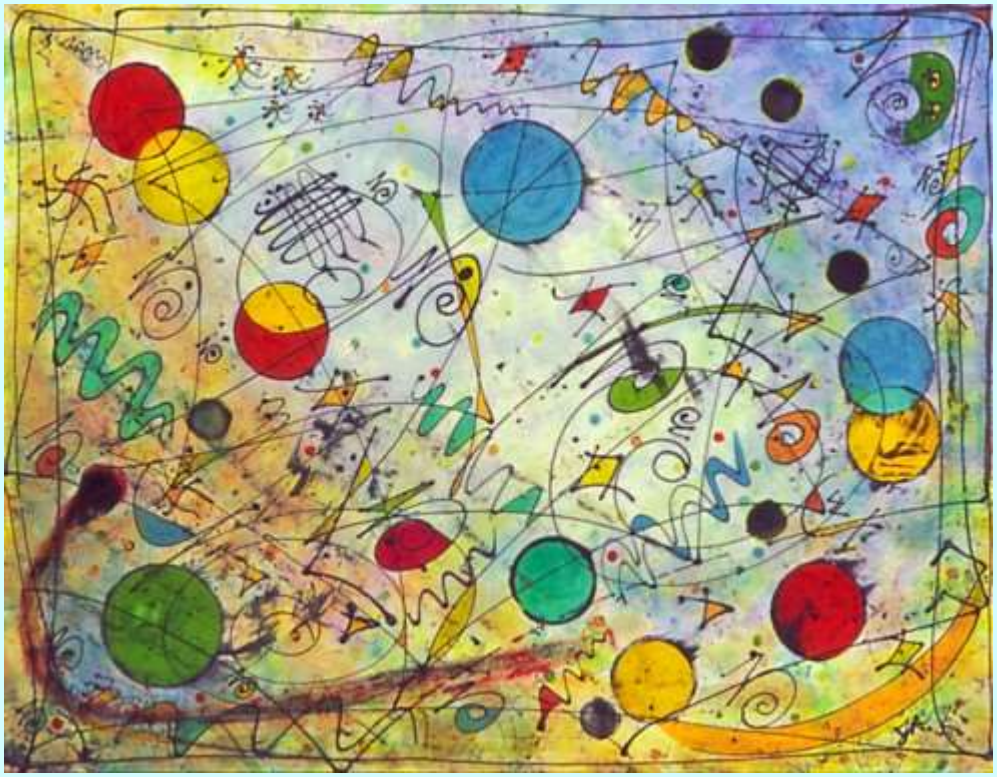
Simplicity and Complexity



John D. Barrow

Is the World Simple or Complicated ?

Motivations for Natural Laws

Monotheism

Dictatorships

Top-down philosophy

Statute laws

Civil government

Hammurabi 1792-1750 BC

The Chinese Corollary

No omnipotent Deity

Emergent philosophy

Bottom-up

Different legal system

'li' and 'fa'

'li' makes external laws

unappealing

Law and Order

Which is ordered ?

...1,0,1,0,1,0,1,0,1,0,1,0...

..1,1,1,0,0,1,0,1,1,0,1,0,..

“COMPRESSION”

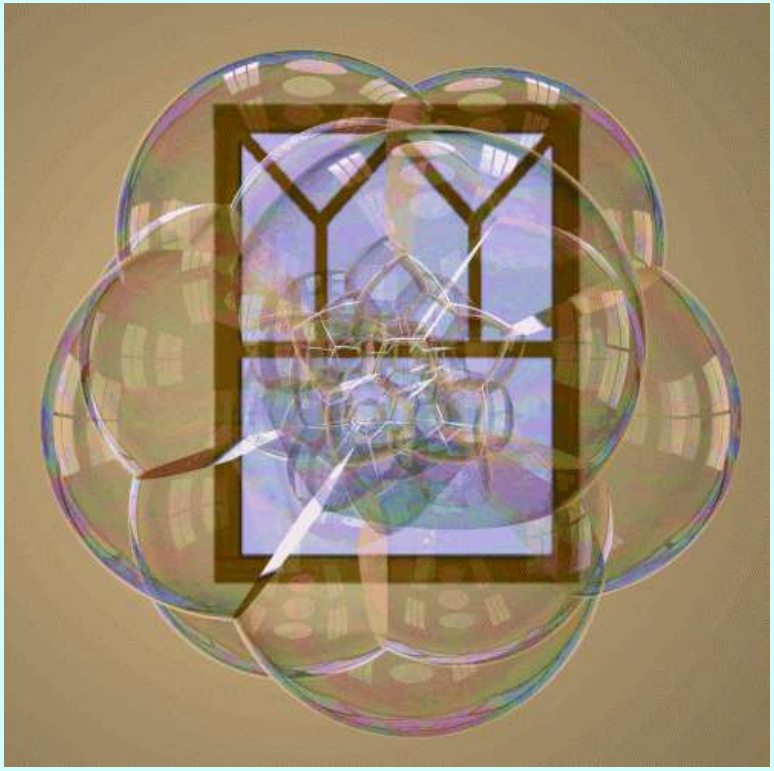
...1,0,1,0,1,0,1,0,1,0,1,0...

..1,1,1,0,0,1,0,1,1,0,1,0,..

Random = Incompressible

Ordered = Compressible

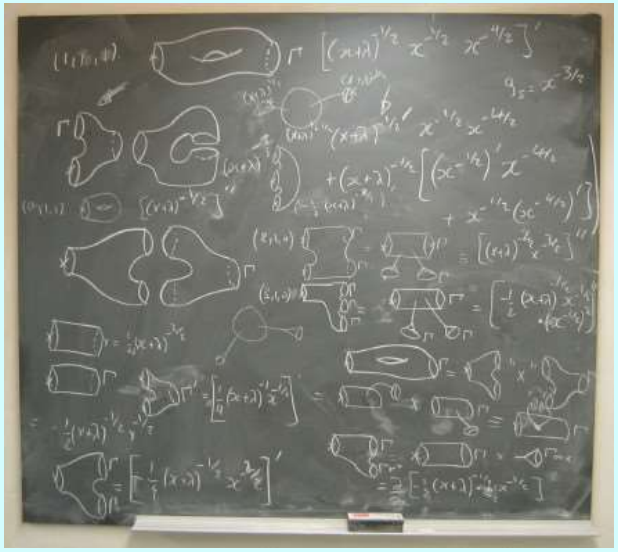
Mathematics
is
The Collection of All Possible Patterns

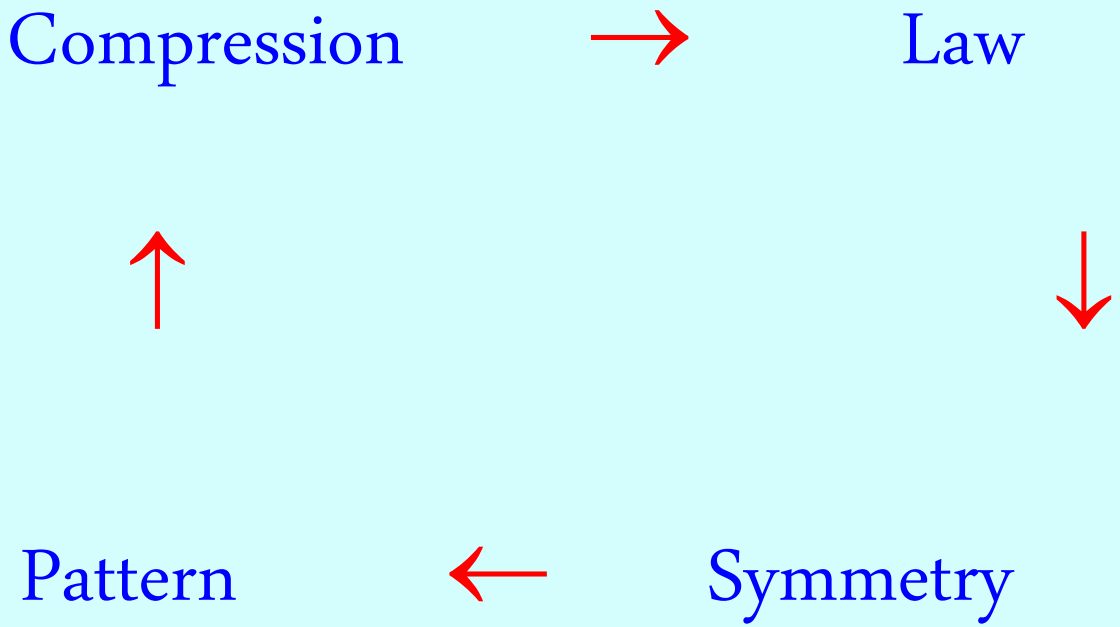


The World must be mathematical

But

Simple mathematics
is
miraculously effective




Compression
Law
Pattern
Symmetry

“Gauge” Theories

Describe all known forces

Gravity,

weak radioactive force,

strong nuclear force,

electromagnetism

Tell you what the laws govern

Symmetry

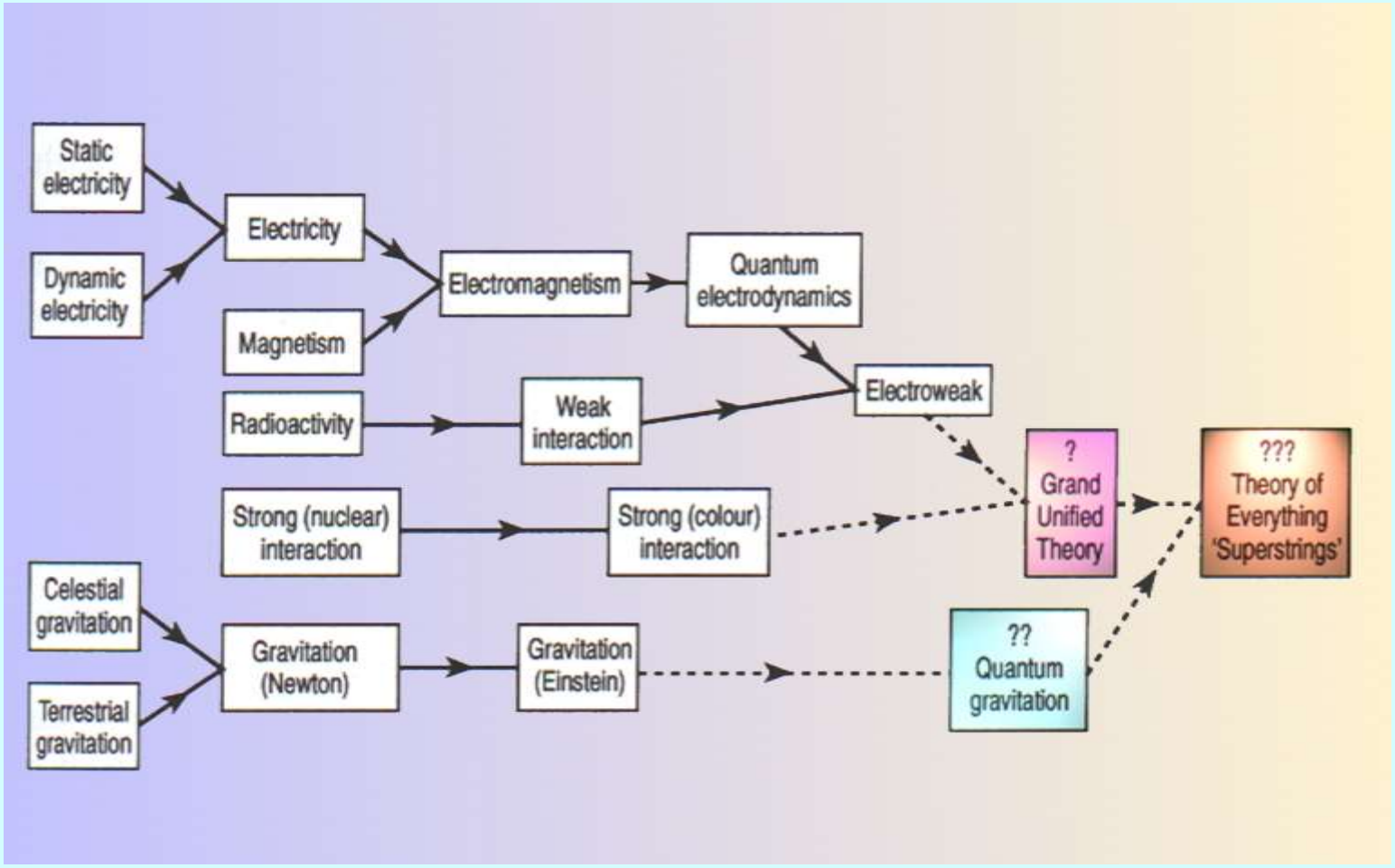
Pattern

→

Possible

Physics theory

Unification?!


Static electricity
Dynamic electricity
Electricity
Magnetism
Electromagnetism
Quantum electrodynamics
Electroweak
Radioactivity
Weak interaction
Strong (nuclear) interaction
Strong (colour) interaction
? Grand Unified Theory
??? Theory of Everything 'Superstrings'
Celestial gravitation
Terrestrial gravitation
Gravitation (Newton)
Gravitation (Einstein)
?? Quantum gravitation

Symmetry

- Why do we like it?
- Symmetry means life
- Lateral symmetry
- Over-sensitivity likely

You live long

and prosper if

you notice symmetry

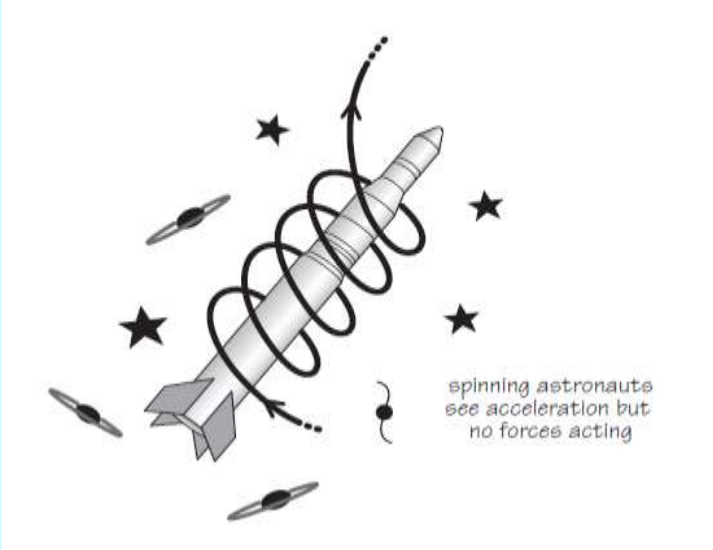
Left-Right

Symmetry

- Mate
- Lunch
- Predator

Newton's Laws Are Un-Copernican

Newton's laws only hold for special observers
who do not rotate or
Accelerate with respect to the fixed stars

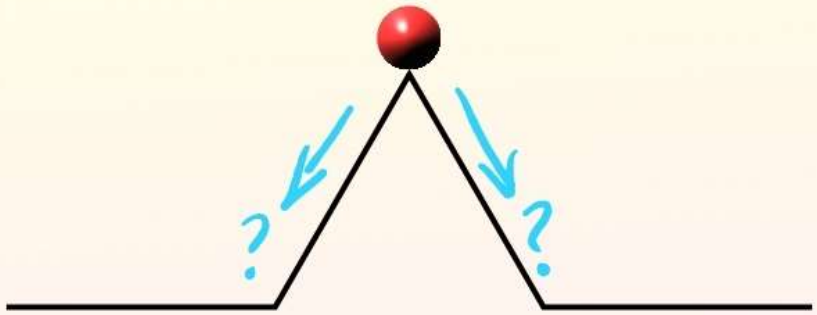


There are special classes of observers for whom the laws of Nature look simpler!!

Einstein's Extends the Copernican Principle from Outcomes to Laws

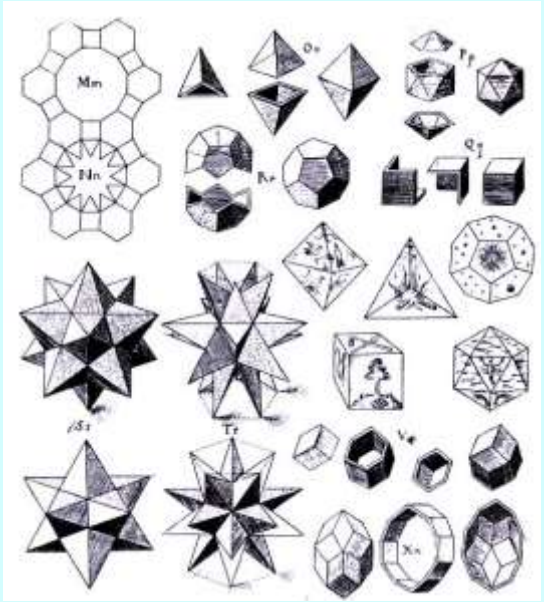
The forms of the laws of nature look the same to ALL observers regardless of their motion

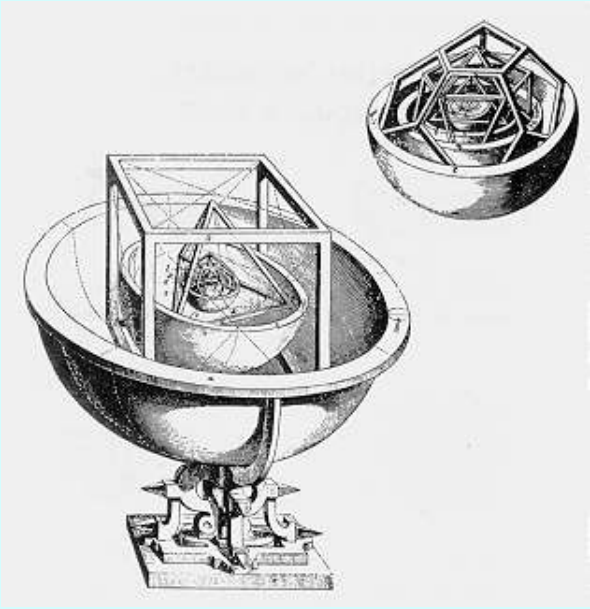
Tensors: $T = S \rightarrow T' = S'$



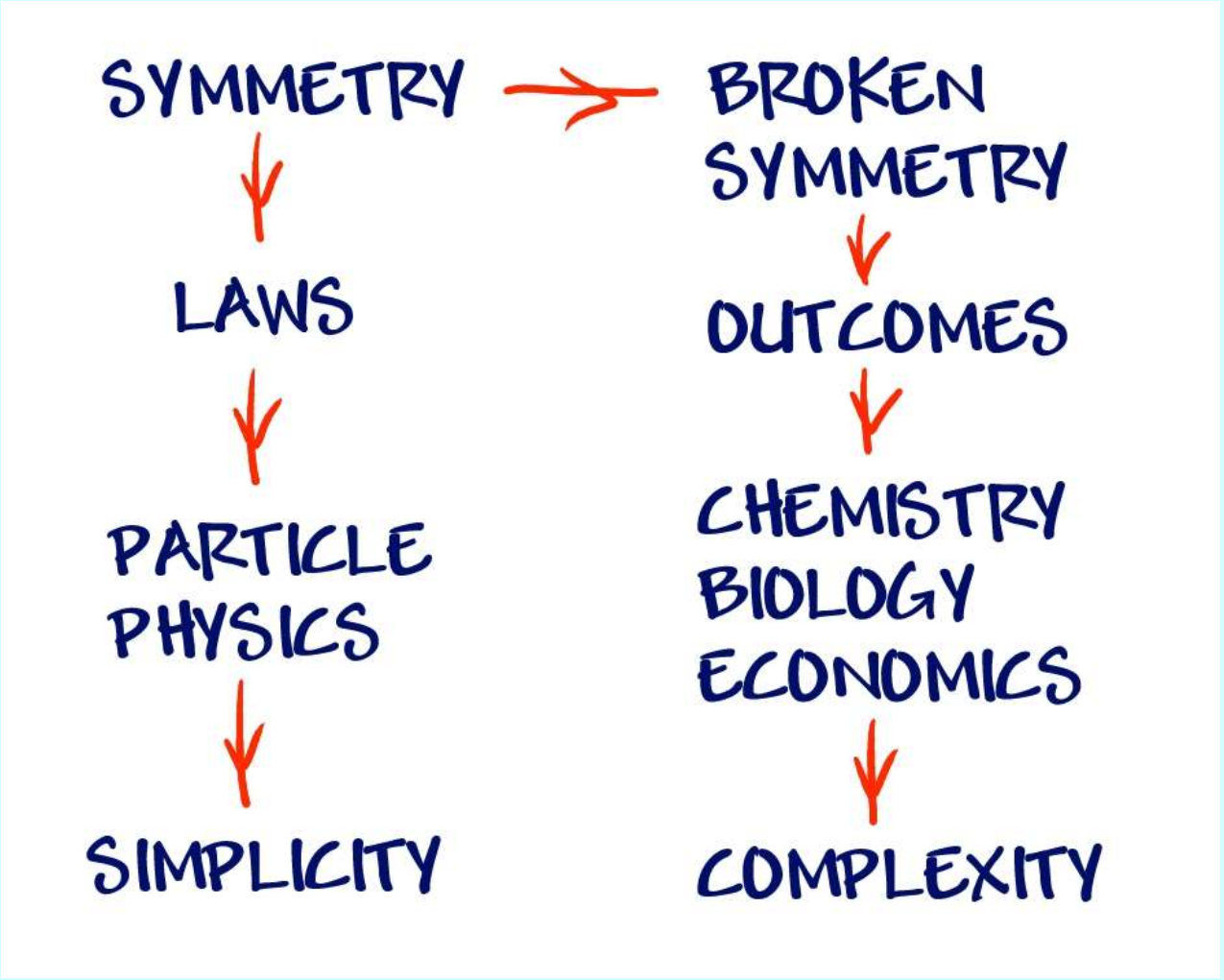
- Outcomes are more complicated than Laws.
- Symmetry breaking
- We see outcomes; not Laws.

The Secret of the Universe





Four
Simple
Symmetrical
Laws
Lead to Many
Complex
Asymmetrical
Outcomes

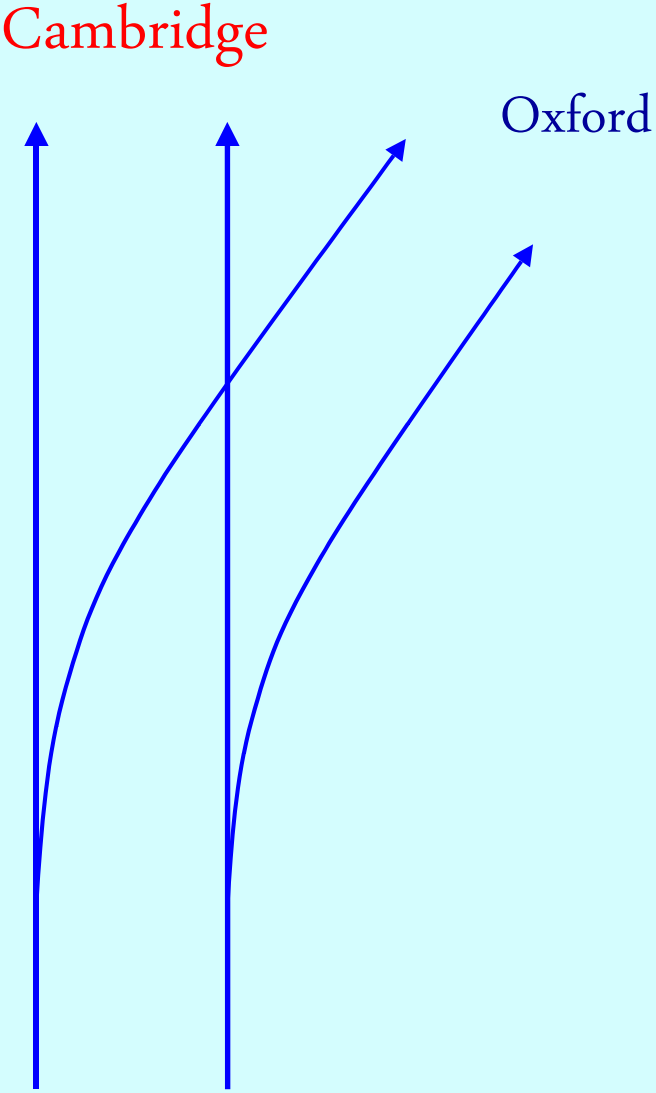

SYMMETRY
BROKEN SYMMETRY
LAWS
OUTCOMES
PARTICLE PHYSICS
CHEMISTRY
BIOLOGY
ECONOMICS
SIMPLICITY
COMPLEXITY

Disorganised Complexity

Vs

Organised Complexity

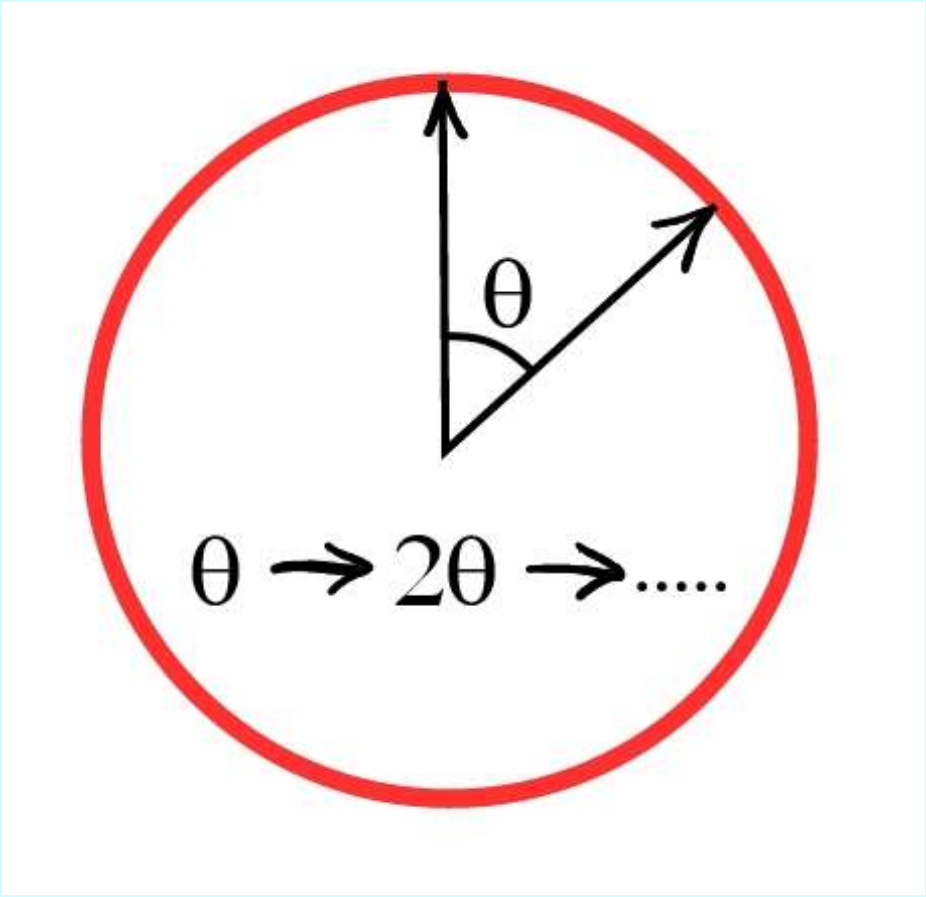
CHAOS
IS
DRAMATIC
SENSITIVITY
TO
IGNORANCE

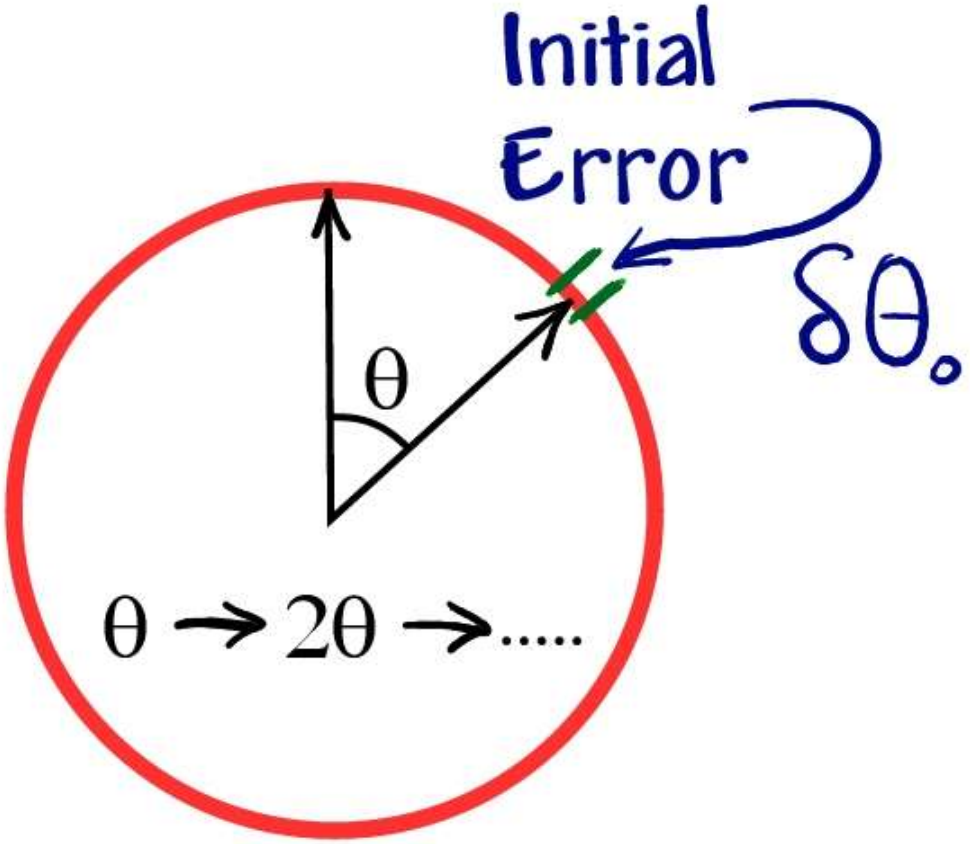


James Clerk Maxwell

1873

"the existence of unstable conditions renders impossible the prediction of future events, if our knowledge of the present state is only approximate, and not accurate."


θ
θ → 2θ → .....



AFTER N STEPS

ERROR = $2^N \delta\theta_0 > 360^\circ$

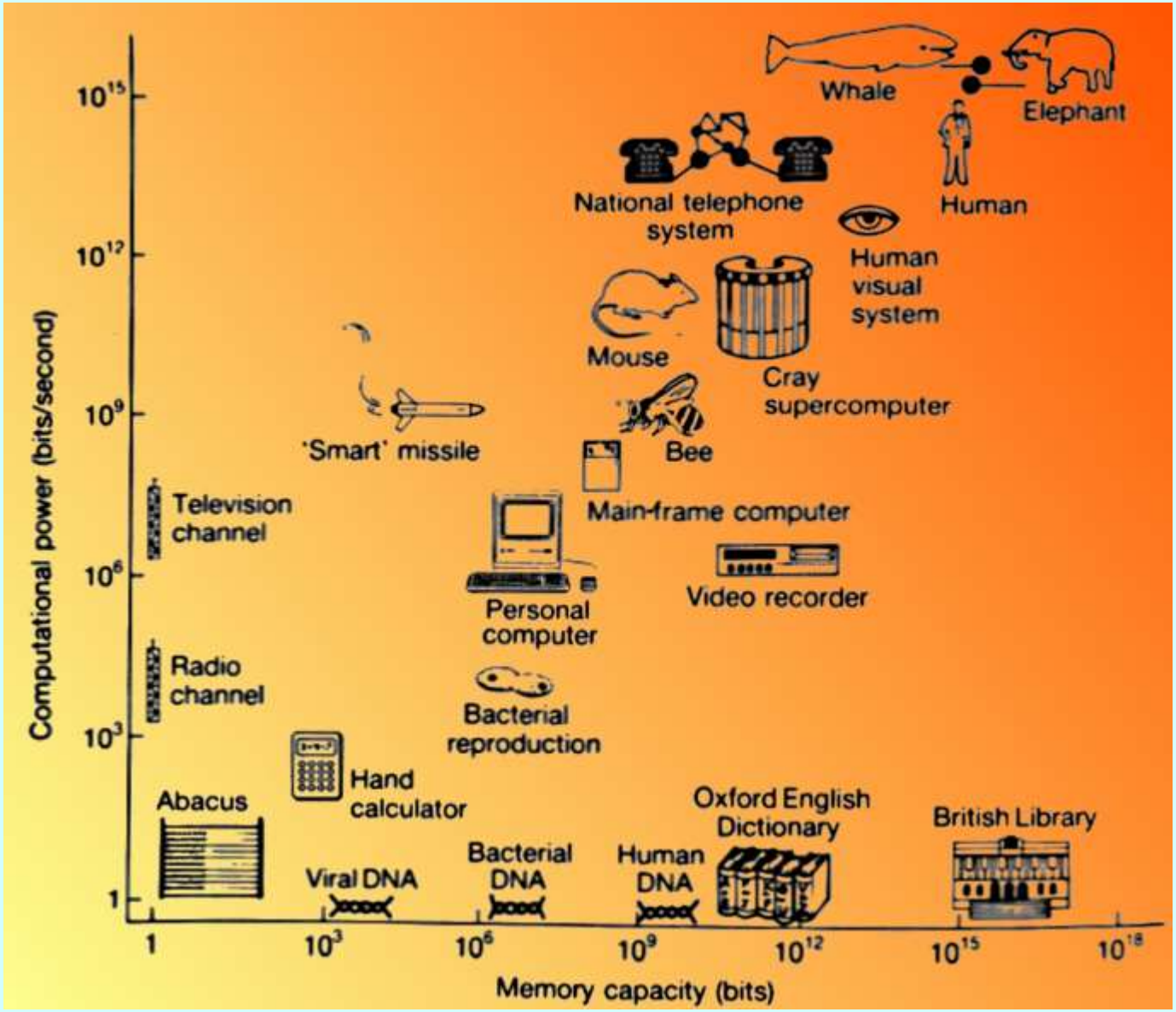
Chaotic motions can have well- behaved Averages

Molecular motions are chaotic

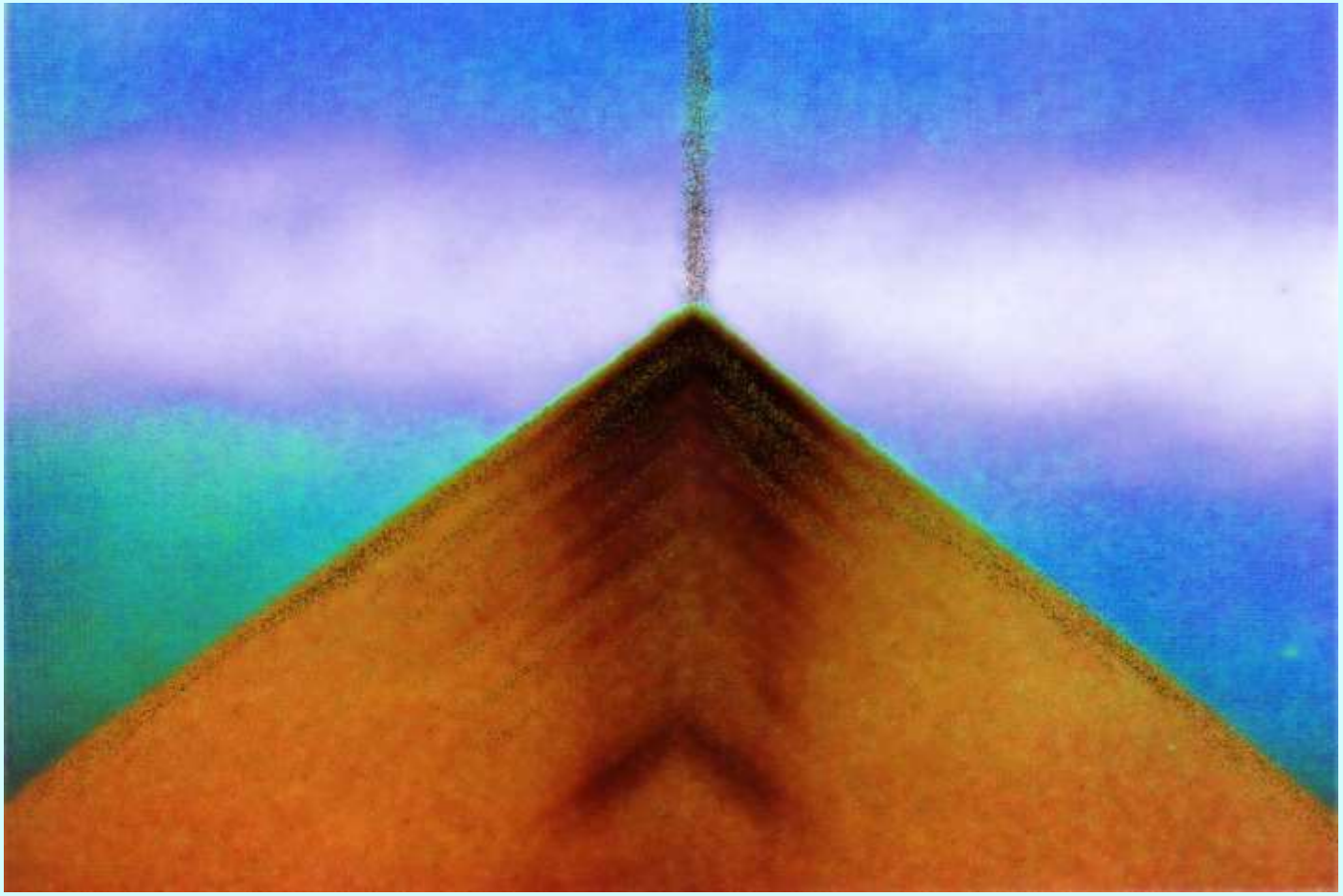
But

PV/T = constant

Organised Complexity


Computational power (bits/second)
10^{15}
10^{12}
10^{9}
10^{6}
10^{3}
1
Whale
Elephant
Human
National telephone system
Human visual system
Mouse
Cray supercomputer
'Smart' missile
Bee
Main-frame computer
Television channel
Personal computer
Video recorder
Radio channel
Bacterial reproduction
Hand calculator
Abacus
Oxford English Dictionary
British Library
Viral DNA
Bacterial DNA
Human DNA
1
10^{3}
10^{6}
10^{9}
10^{12}
10^{15}
10^{18}
Memory capacity (bits)

Sandpiles,
Meandering Rivers
and
Reluctant Dogs




`Critical'
State
Avalanches
of all sizes
Frequency ∝ (Size)^N
SELF-ORGANISING CRITICALITY

Complexity
with reductionism
is science

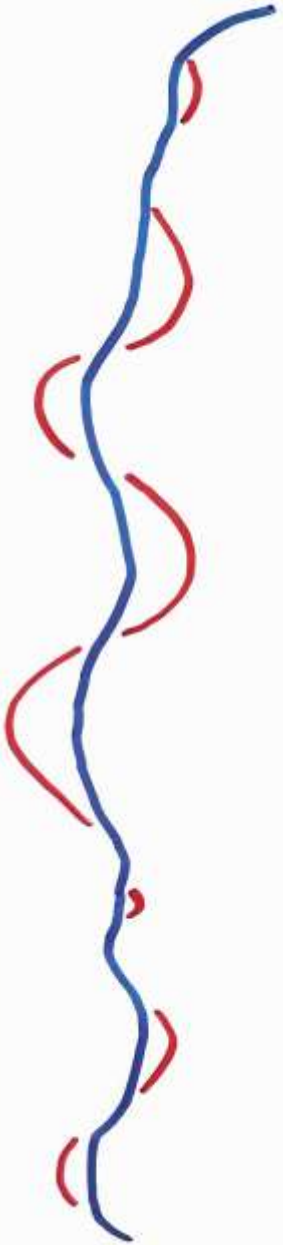
Complexity
without reductionism
is art

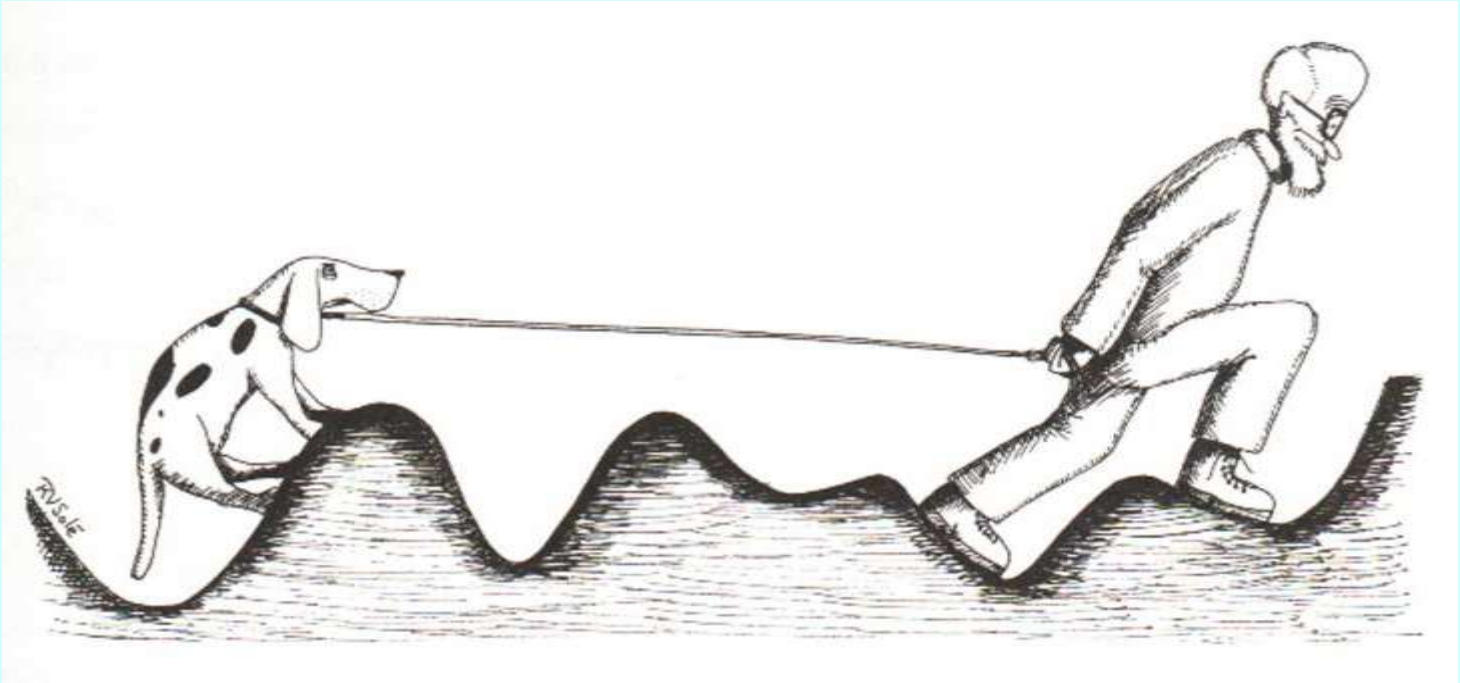
Gabriel Orozco, Sand on Table, 1992

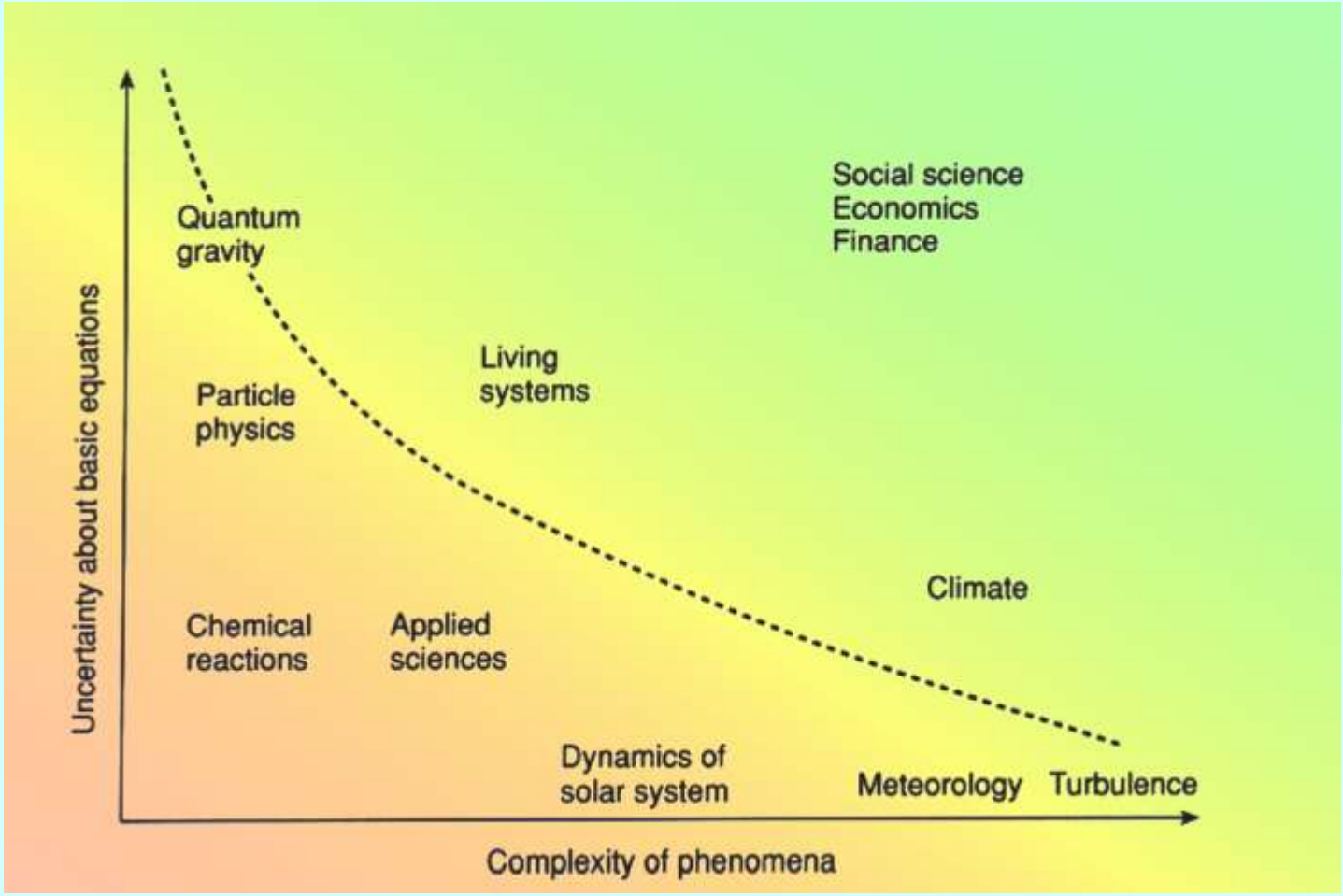
Kanuti River, Alaska

Ecuador

Oxbow Lakes






Uncertainty about basic equations
Quantum gravity
Social science
Economics
Finance
Living systems
Particle physics
Climate
Chemical reactions
Applied sciences
Dynamics of solar system
Meteorology
Turbulence
Complexity of phenomena