Reflections on Physics, Computation, Science and Apps: 1964 - 2014

Claes Johnson

Summary of 50 Years: Finite Elements 1964-2014

From Analytical to Computational Mathematics

From Formal/Symbolic to Constructive Math

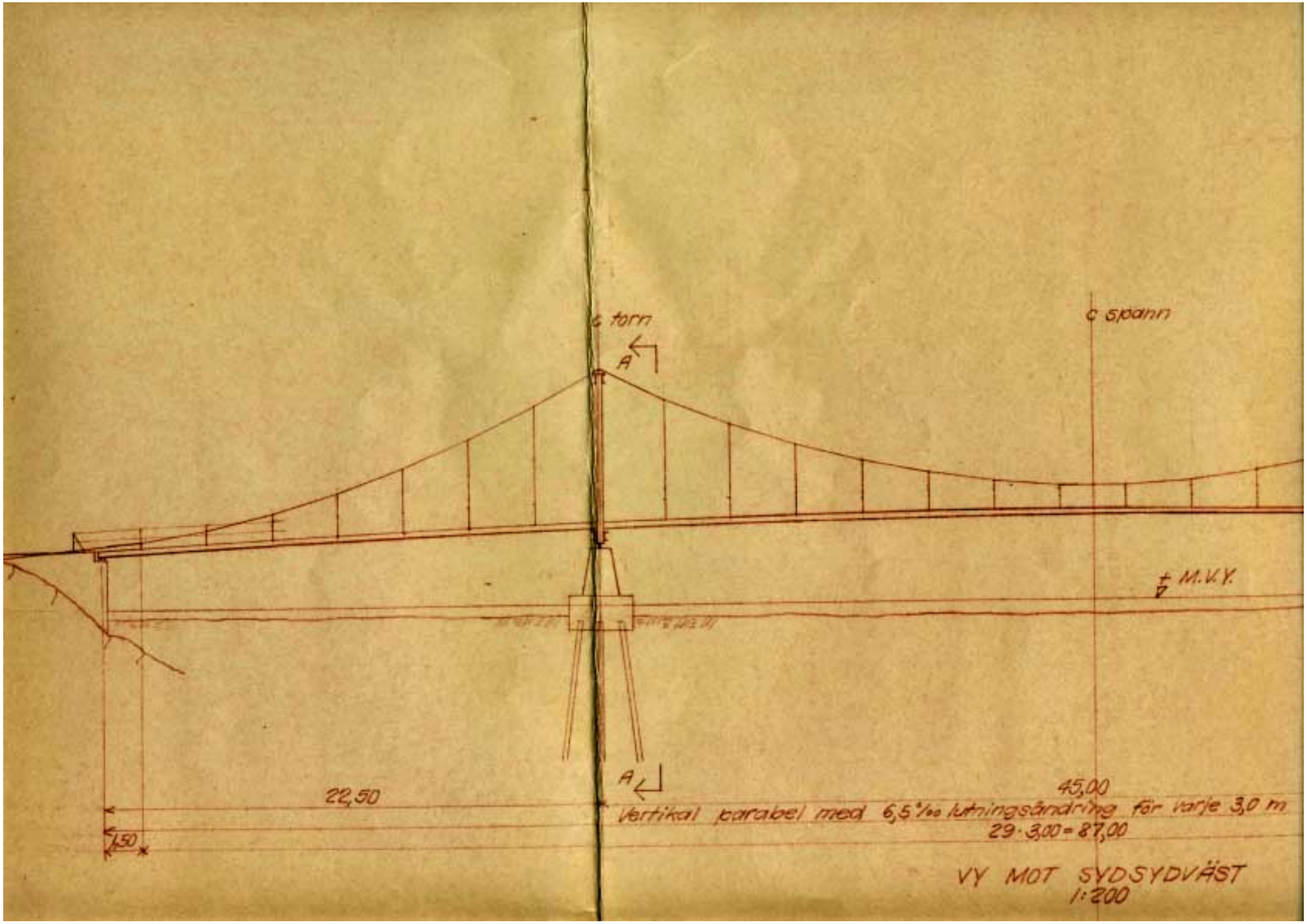
From Slide Rule to Computer

From Calculus to Computational Calculus

Good Students - Able Coworkers - Friendly Collegues

Älvsborg Bridge 1963- Asplund: Matrix Methods First Computer

Design-Computation



Nov 13 2014

Mechanics-Mathematics

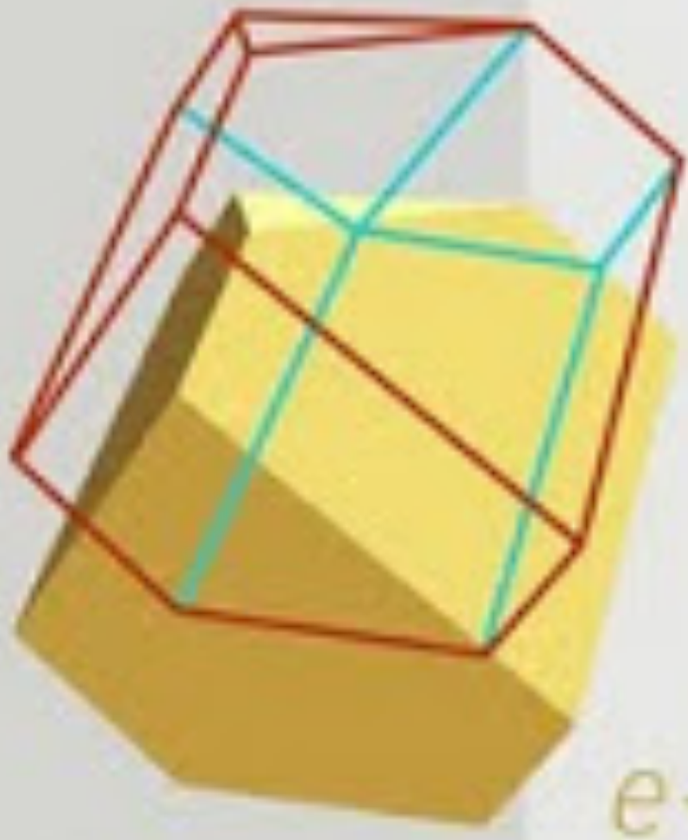
- **Mechanics: Alf Samuelsson: Analysis of Frame Structures by Algebraic Topology: Matrix methods**

- **Mathematics: Thomee-Gårding-Courant-Hilbert-Lagrange-Euler**

- **Variational Energy Methods: Computational PDEs**

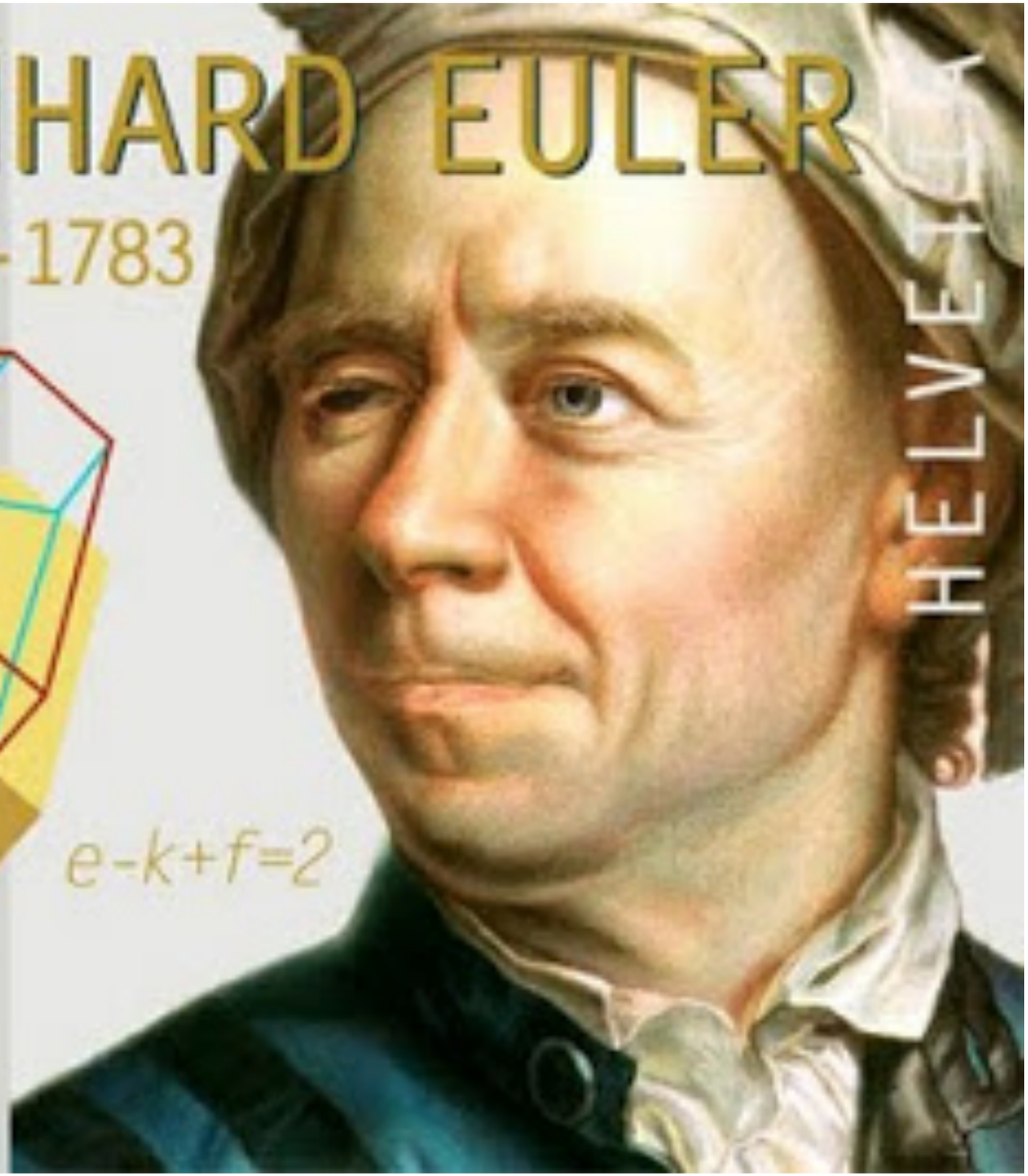
LEONHARD EULER

1707-1783

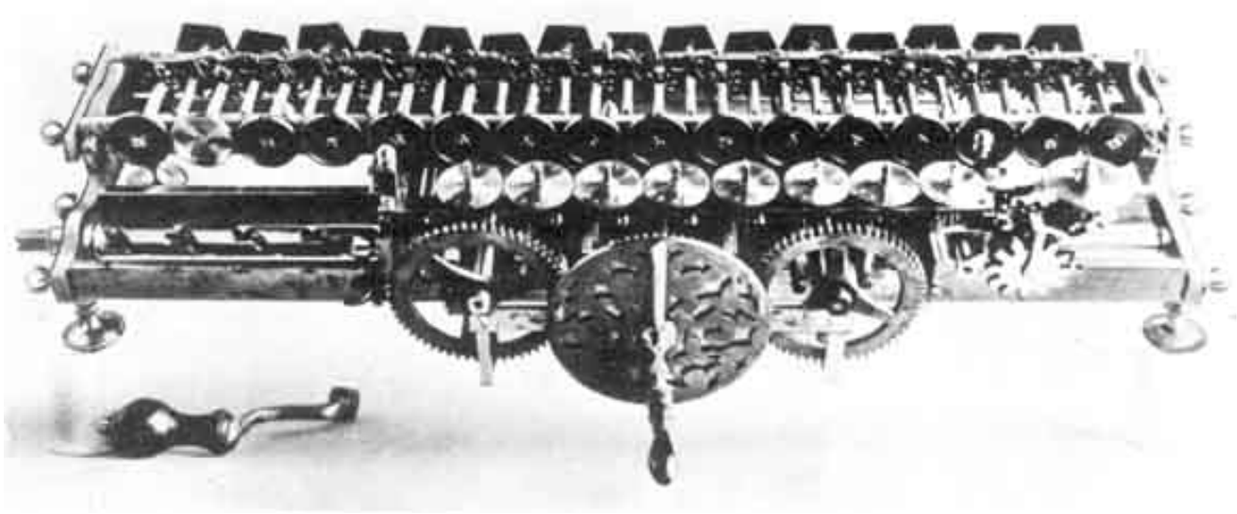


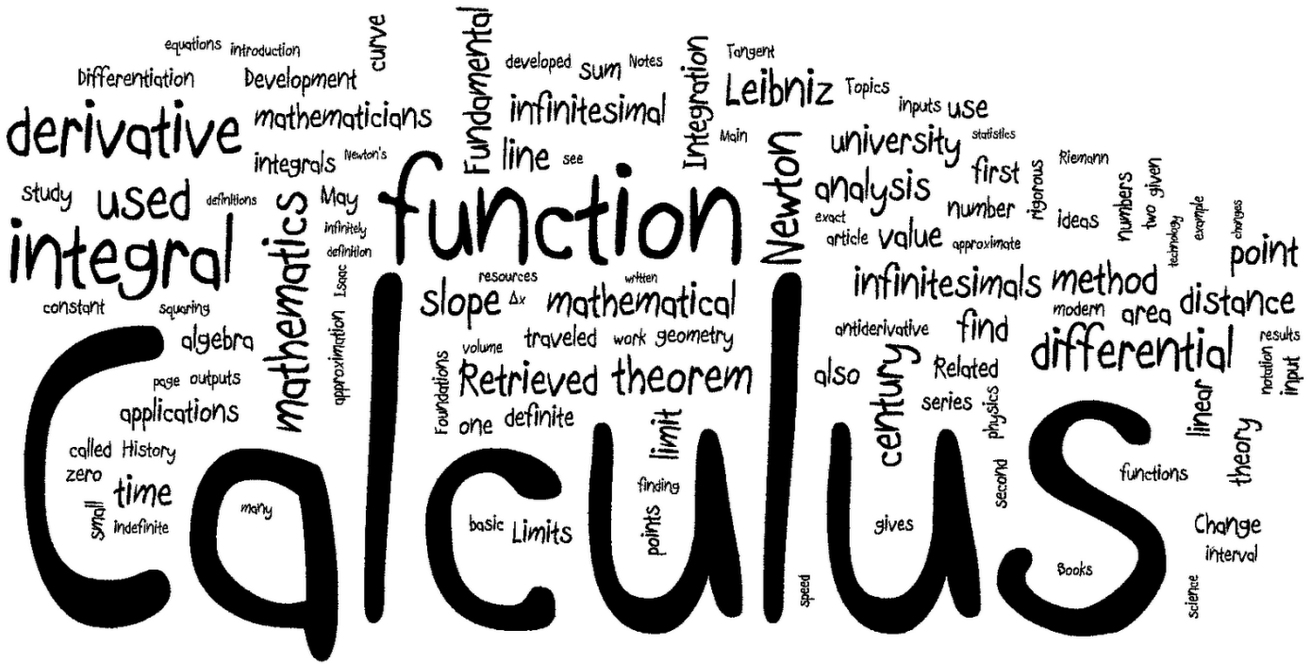
$e-k+f=2$

130



Leibniz Calculator





Our Tools

- **Discretization - FEM - Galerkin Weak Variational Method - Residual**
- **Construction - Digital Computation**
- **Stability**
- **A posteriori Output Error - Computability**
- **Turbulence, 2nd Law, Theory of Flight**

An Experiment:

- **Apply Our Tools to**
- **Modern Physics**
- **Climate Science**
- **Math Education**
- **Result??**

Principle of Computation-Simulation

Physics =

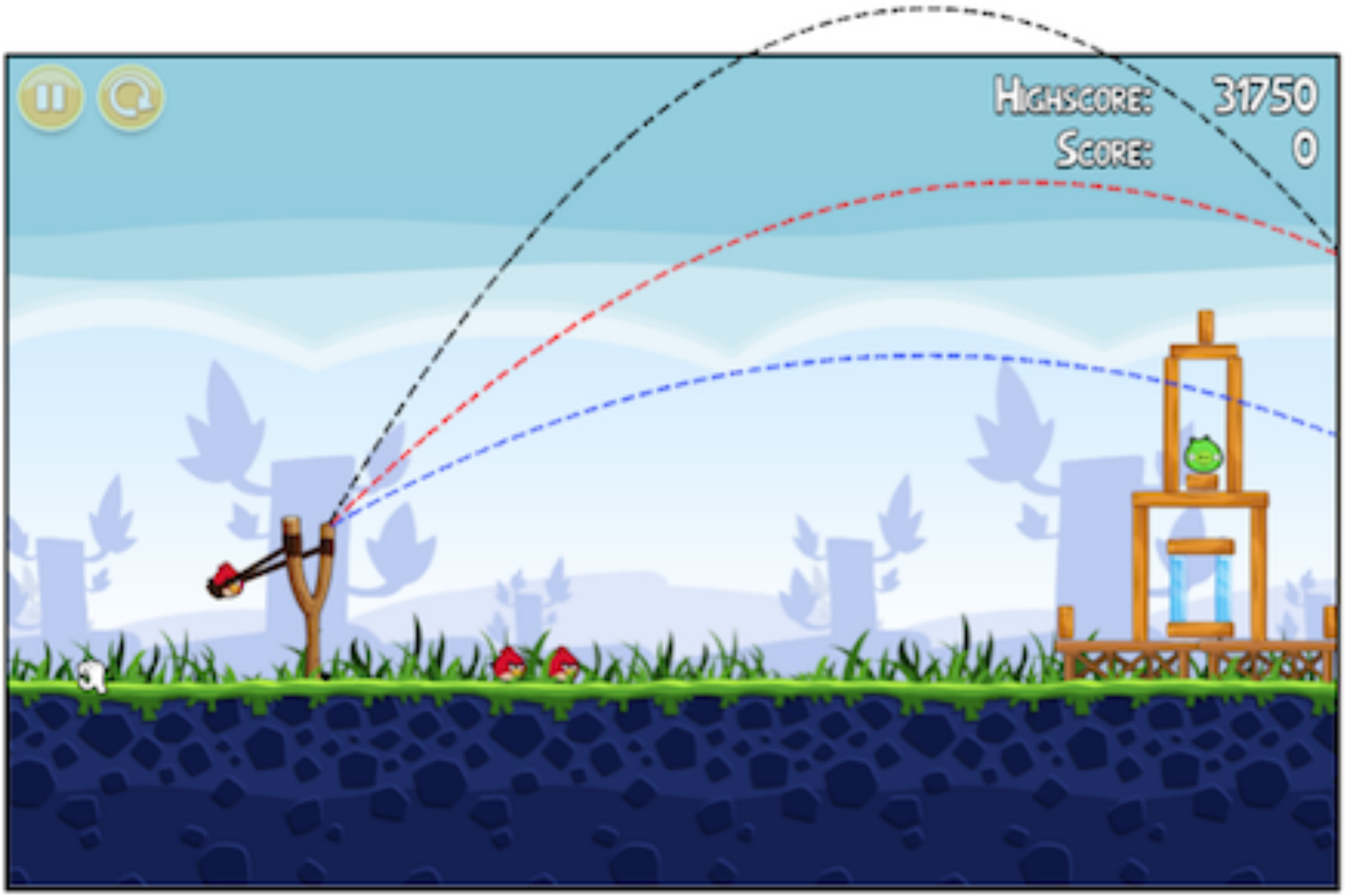
Analog Finite Precision Computation

Simulated by

Digital Finite Precision Computation

= App - Analog Computation/Google

Angry Birds: 2 Billion Users



Booming World of Apps

- **App =Interactive Computational Math Model**
- **Angry Birds...Computer Game**
- **GPS**
- **Music Studio, Physics/Chemistry/Science Lab**
- **Education/Practice: Construct + Use Apps**

Physics = Constructive Physics: Elements + Forces = FEM

Finite Element Principle

- **Microscopics-Elements-Simple**
- **Macroscopics-System-Complex**
- **Complex Microscopics Impossible??**

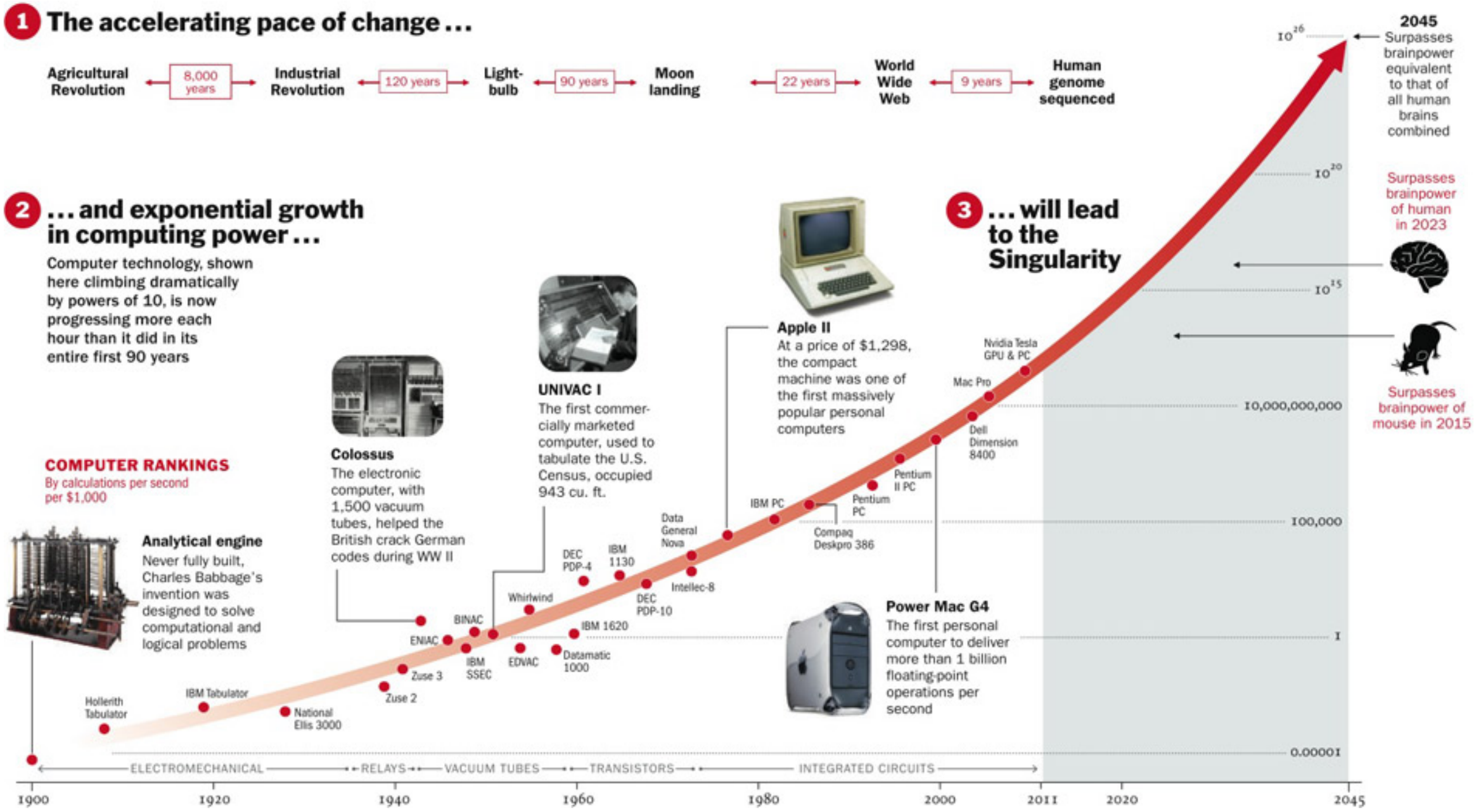
Constructive vs Formal Math-Physics

- **Constructed Object: A posteriori**
- **= Existence + Understanding**

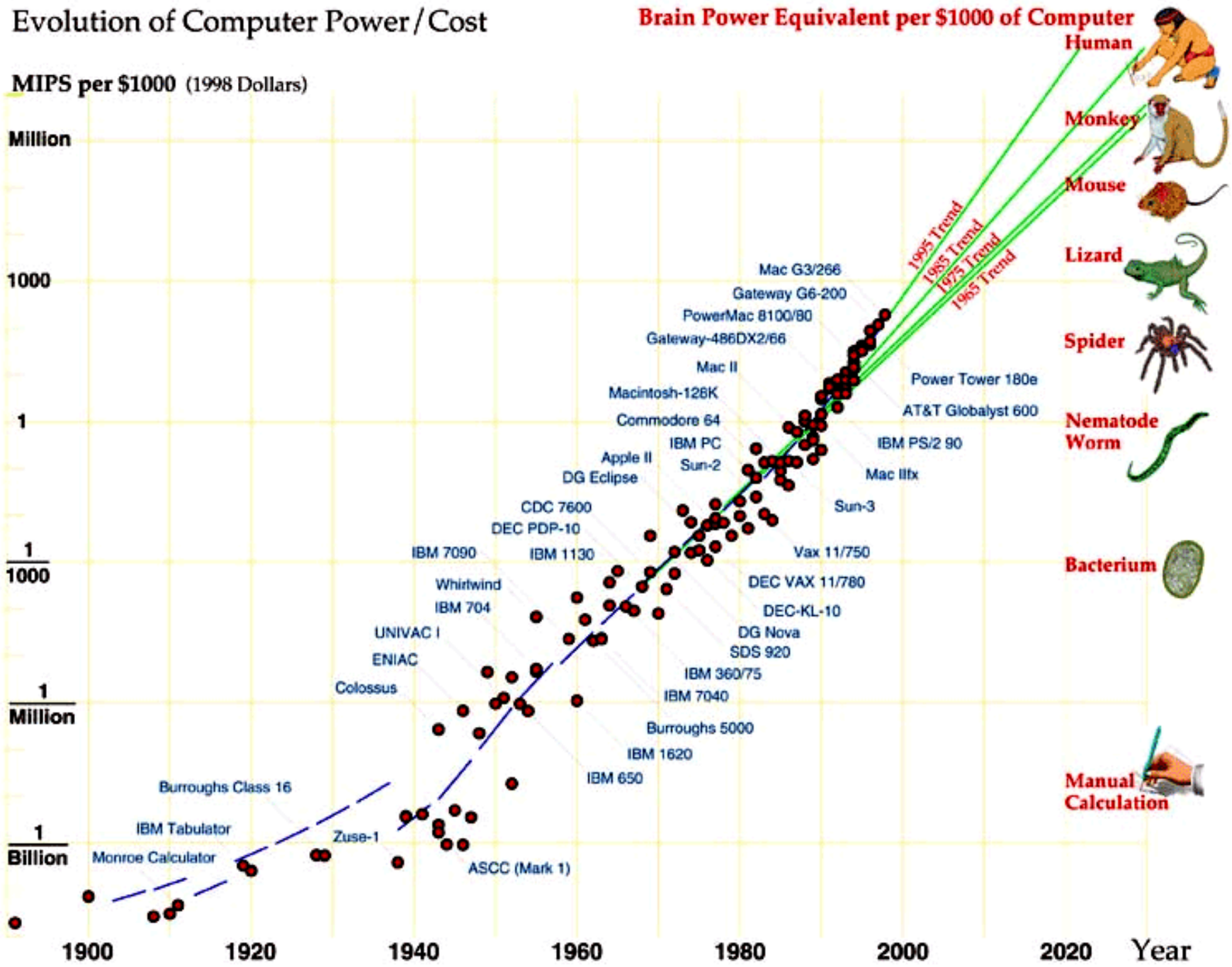
- **Formally Defined Object: A priori**
- **Existence?? Understanding??**

- **Math War 1930s: Constructivists Science Winners.**
- **But Formalists Filled Math Departments!!**

The Singularity: 2045
FEM-Center Singularity 2007



2020 Computer = Human Brain



Birth of Modern Physics 1900:
(before the Computer)

Special Relativity 1905

Quantum Mechanics 1925

Blackbody Radiation 1900

Theory of Flight 1904

2nd Law of Thermodynamics 1850-1900

End of Modern Physics 2000:

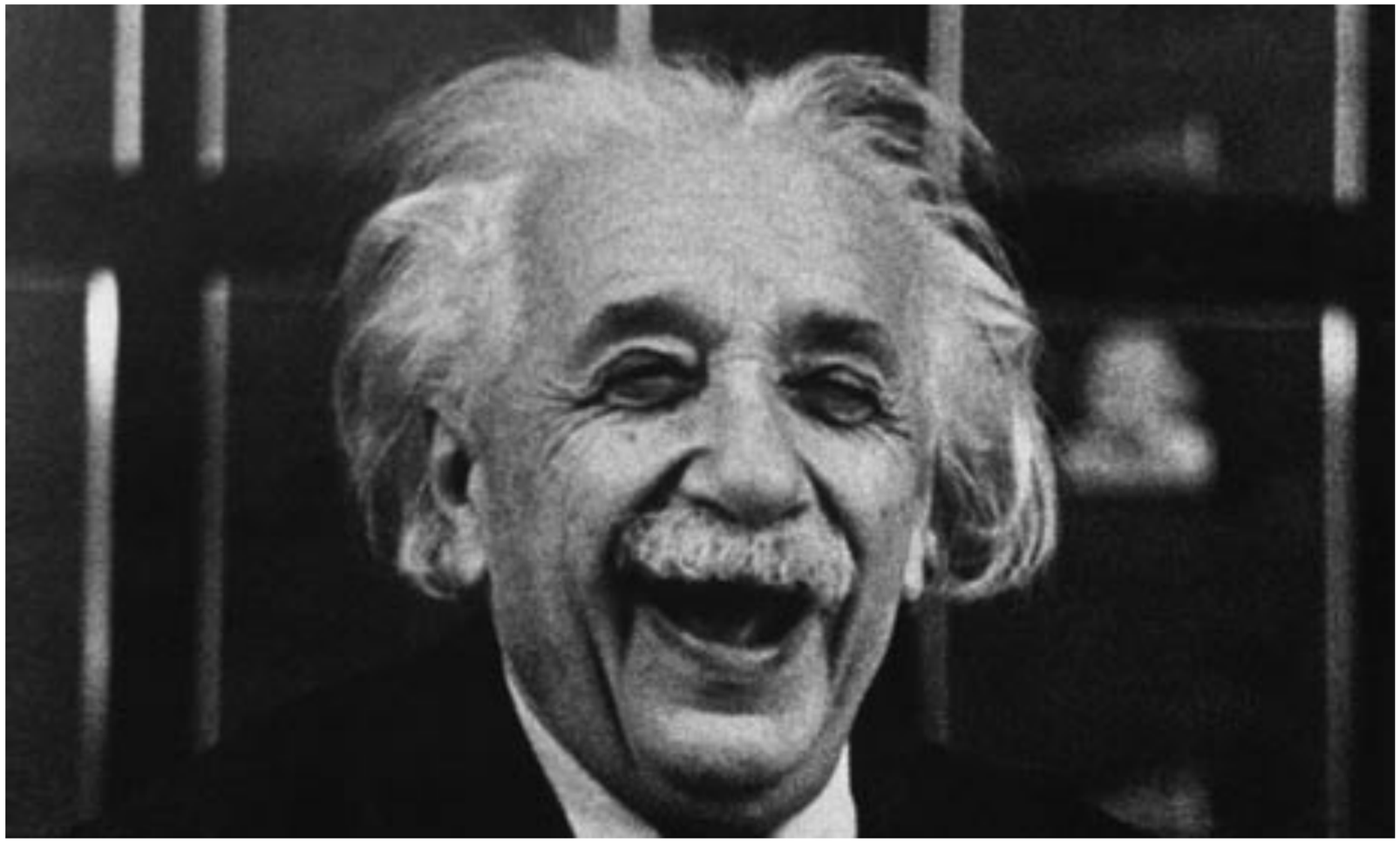
Relativity and QM incompatible

String theory: Infinitely Small

Multiversa: Infinitely many Universa
Infinitely Large

Uncomputable-Unobservable-
Not Understandable: Unphysical

Theory of Relativity



Newton, forgive me!
I neglected mathematics…because my intuition was not strong enough to differentiate the fundamentally important from the dispensable erudition…

Principle of Relativity

- **Physical laws take the same form in all inertial systems = Covariance.**
- **The same wave equation for all inertial observers.**
- **Speed of light the same for all inertial observers**

Special Relativity = Lorentz Transformation

$$x' = C\,(x - vt)$$

$$t' = C\,(t - vx)$$

$$C = 1/(1- v^2)$$

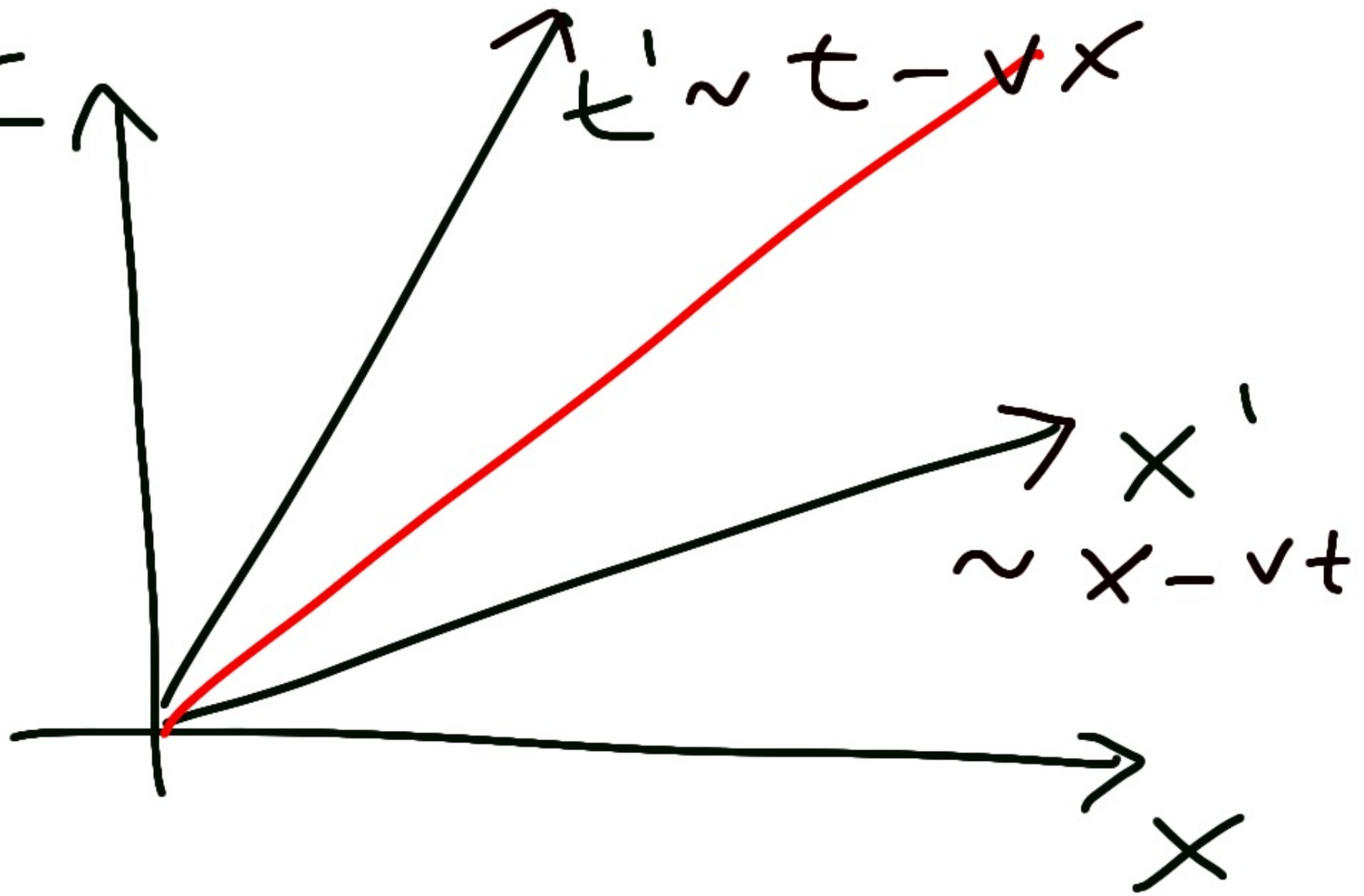
Two observers O and O' moving with relative velocity v. Speed of light = 1 > v.

Einsteinian space-time point event:

(x,t) observed by O. (x',t') observed by O'.

Different observations of same event event!!

Einstein's Two Observers:



Wave equation invariant: Principle of Relatvity:

$$d2/dt2 - d2/dx2 = d2/dt'2 - d2/dx'2 = 0$$

But not initial data:

$$u'(x',0)=u(Cx',Cvx'),\ d/dt'u'(x',0)=C(d/dt +vd/dx)u(Cx',Cvx')$$

O and O' observe

- same space-time point events
- but different phenomena/physics
- No space contraction. No time dilation.
- SR non-physical
- SR non-physical illusion

Hannes Alfven Nobel Prize 1970

Many people probably felt relieved when told that the true nature of the world could not be understood except by Einstein and a few other geniuses who were able to think in four dimensions. They had tried to understand science, but now it was evident that science was something to believe in, not something which should be understood.

"We have to learn again that science without contact with experiments is an enterprise which is likely to go completely astray into imaginary conjecture."

Hannes Alfven

Many-Minds Relativity

Observer O fixed to origin of x-axis

Observer O' fixed to origin of x'-axis

O and O' use same type of clock fixed to origin

O observes only in (x,t), O' observes only in (x',t')

Coordination of observations

Choice of x-axis in Maxwell's equations

Quantum Mechanics
Schrödinger Equation for N Particles:
Wave Function ψ(x1,x2,...,xN;t)

Dimension = 3N + 1

Computational work = exp(3N)

Uncomputable for N>10

Physics = Computable Physics

Quantum Mechanics = Non-Physics

QM: Not Computable
QM: Not Understandable

Nobody claims to understand QM:

Nobody claims to understand Pauli's Exclusion Principle

Nobody claims to understand why electronic wave functions must be anti-symmetric

No reason to believe that atoms play dice = Microscopics upon Microscopics

The Known Unknown Secret

If you are not completely confused by quantum mechanics, you do not understand it. (John Wheeler)

It is safe to say that nobody understands quantum mechanics. (Richard Feynman)

If [quantum theory] is correct, it signifies the end of physics as a science. (Albert Einstein)

I do not like [quantum mechanics], and I am sorry I ever had anything to do with it. (Erwin Schrödinger)

Quantum mechanics makes absolutely no sense. (Roger Penrose)

We don't understand M-theory String Theory (Ed Witten)

Schrödinger left QM

Approximate Solution AS of Schrödinger Equation SE

AS= OBS: evidence that SE Correct

AS not= OBS: evidence that AS notCorrect:
thus SE = Correct

Fool-Proof that SE 100% Correct

End of Physics:
End of Rationality

CO2 Global Warming Alarmism

Politically Correct Incorrect Science

without Rational Physics Basis

Mass Hysteria: Zero Emission 2050:
Sweden leads World into Stone-Age

Coworker Konrad 9 Years

Apps: Math Education Reform - Preschool - School - University

- Angry Birds Math
- Atoms
- Blackbody Radiation
- Calculus
- Binary Computation
- Anything....

Finite Element Atomic Physics

atom/ion = N electrons around kernel of charge Z

Coulomb attraction kernel-electron

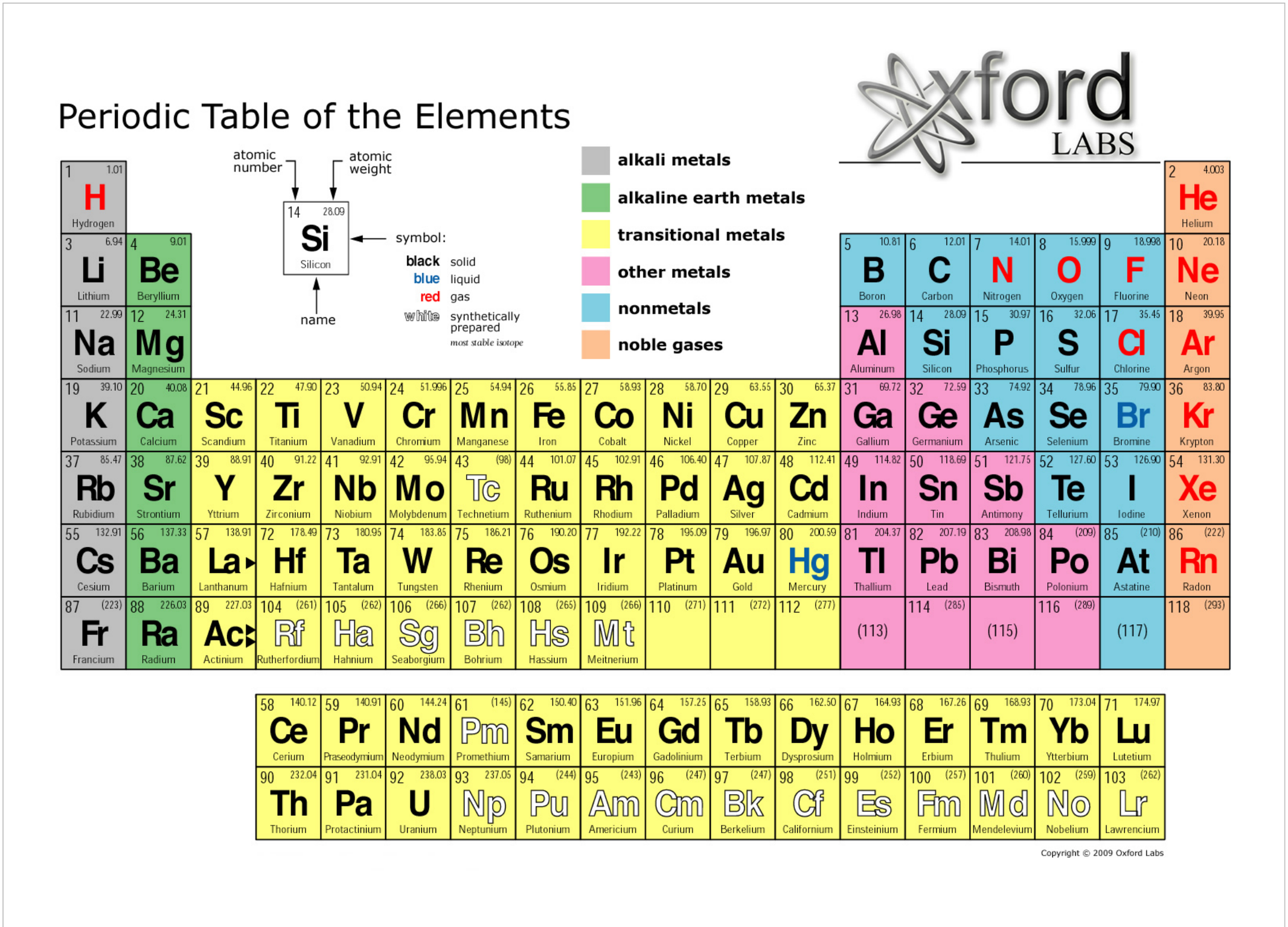
Each electron = "cloud" of "width" 1/Z, 1/(Z-2), 1/(Z-10),..
Coulomb repellation between different electron clouds

kernel-electron potential energy
electron-electron potential energy
electron kinetic energy ~ width^2

System of N wave functions Psi_i(x,t), i = 1,..., N

Computable N-body problem ~ Hartree Model

Periodic Table App



End of Physics:
End of Rationality

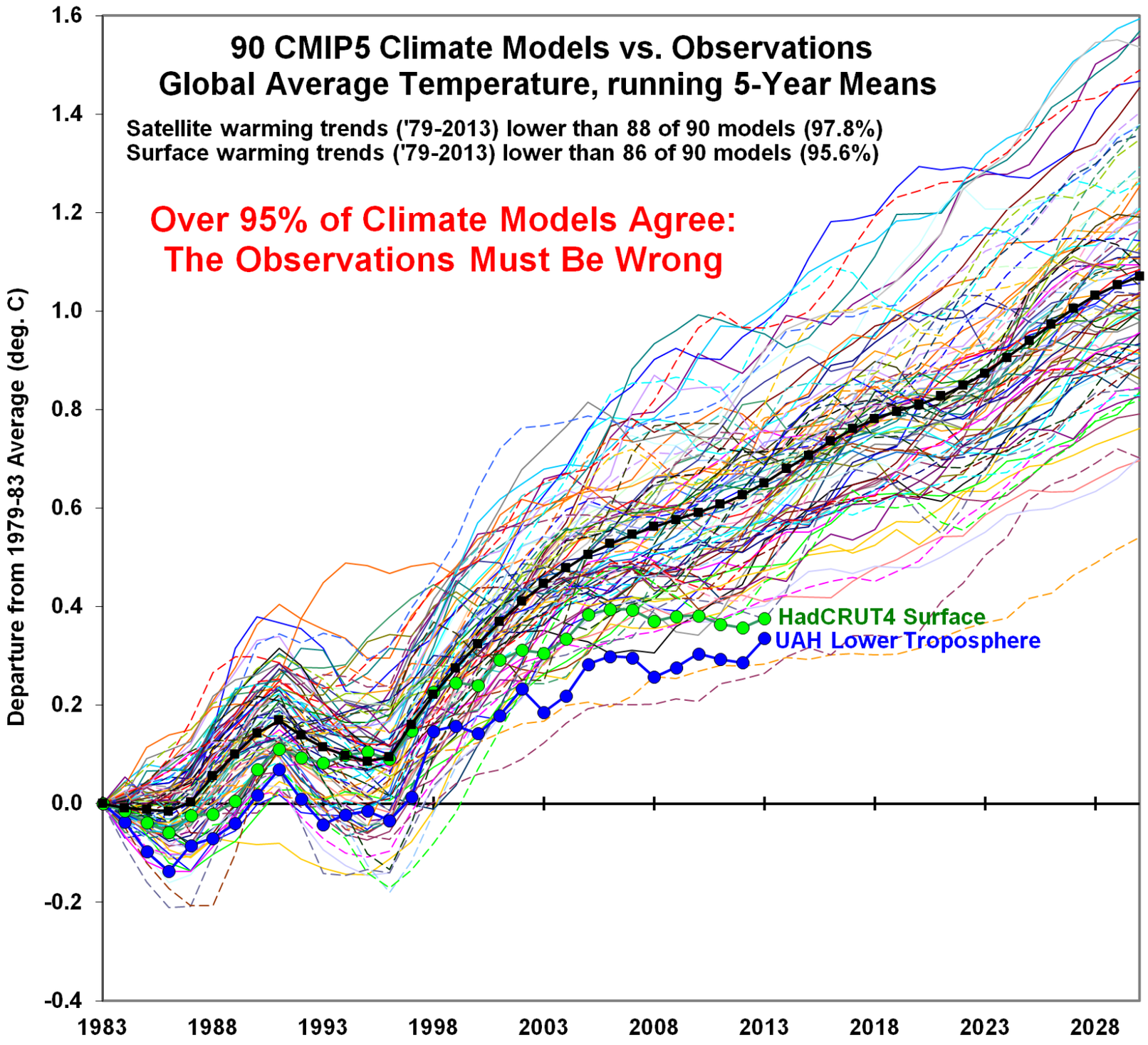
CO2 Global Warming Alarmism

Politically Correct Incorrect Science

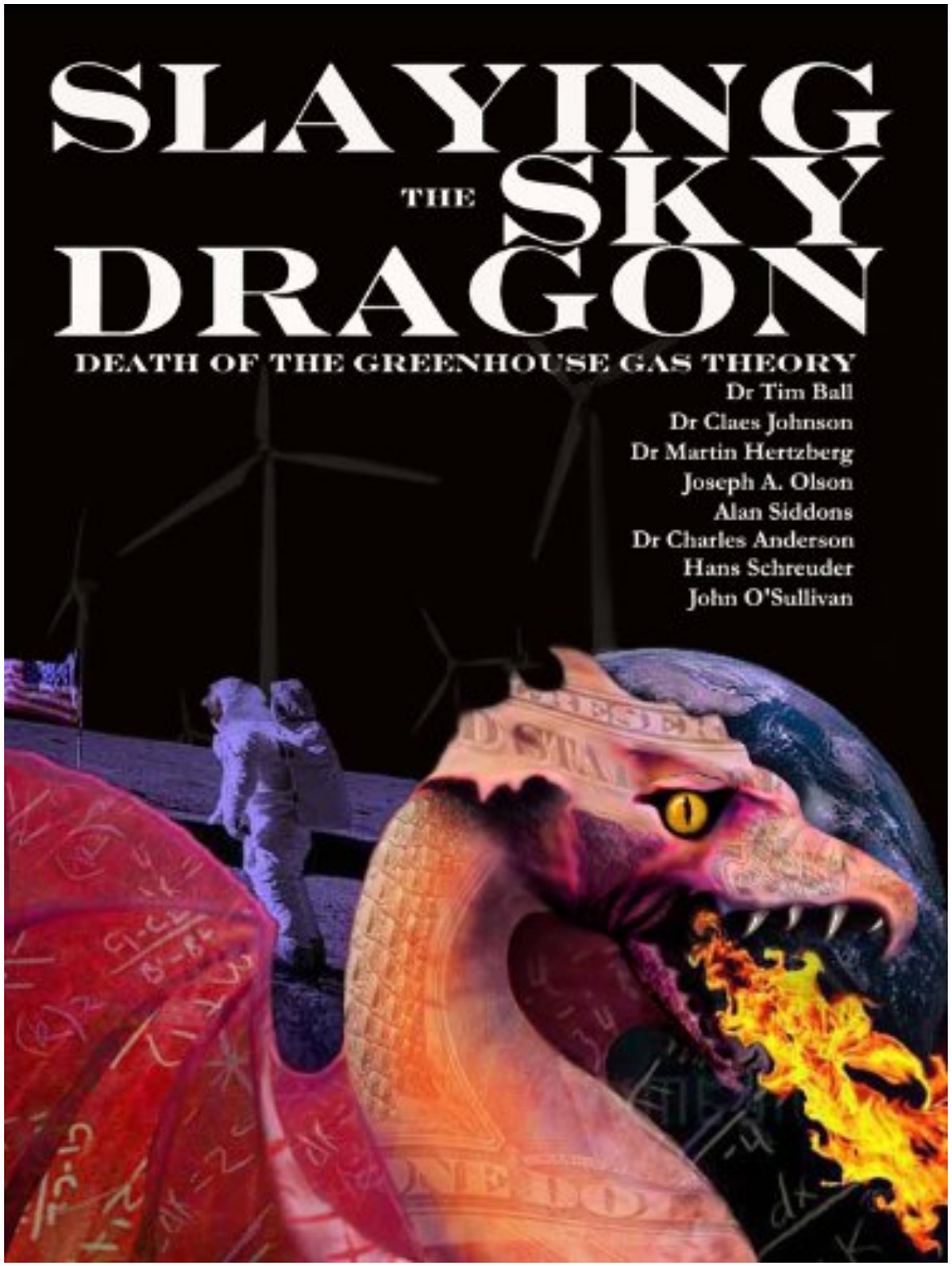
without Rational Physics Basis

Mass Hysteria

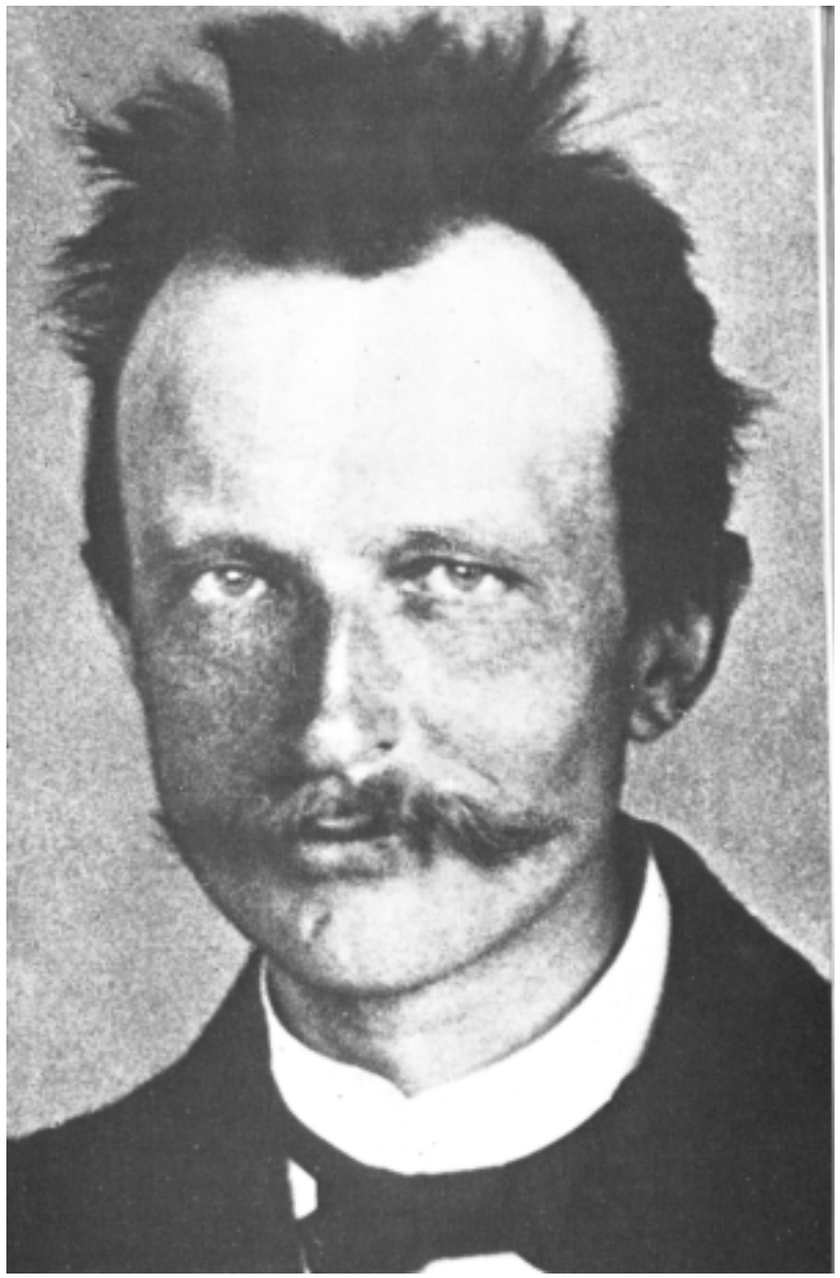
Observation vs Simulation



Blogosphere Science



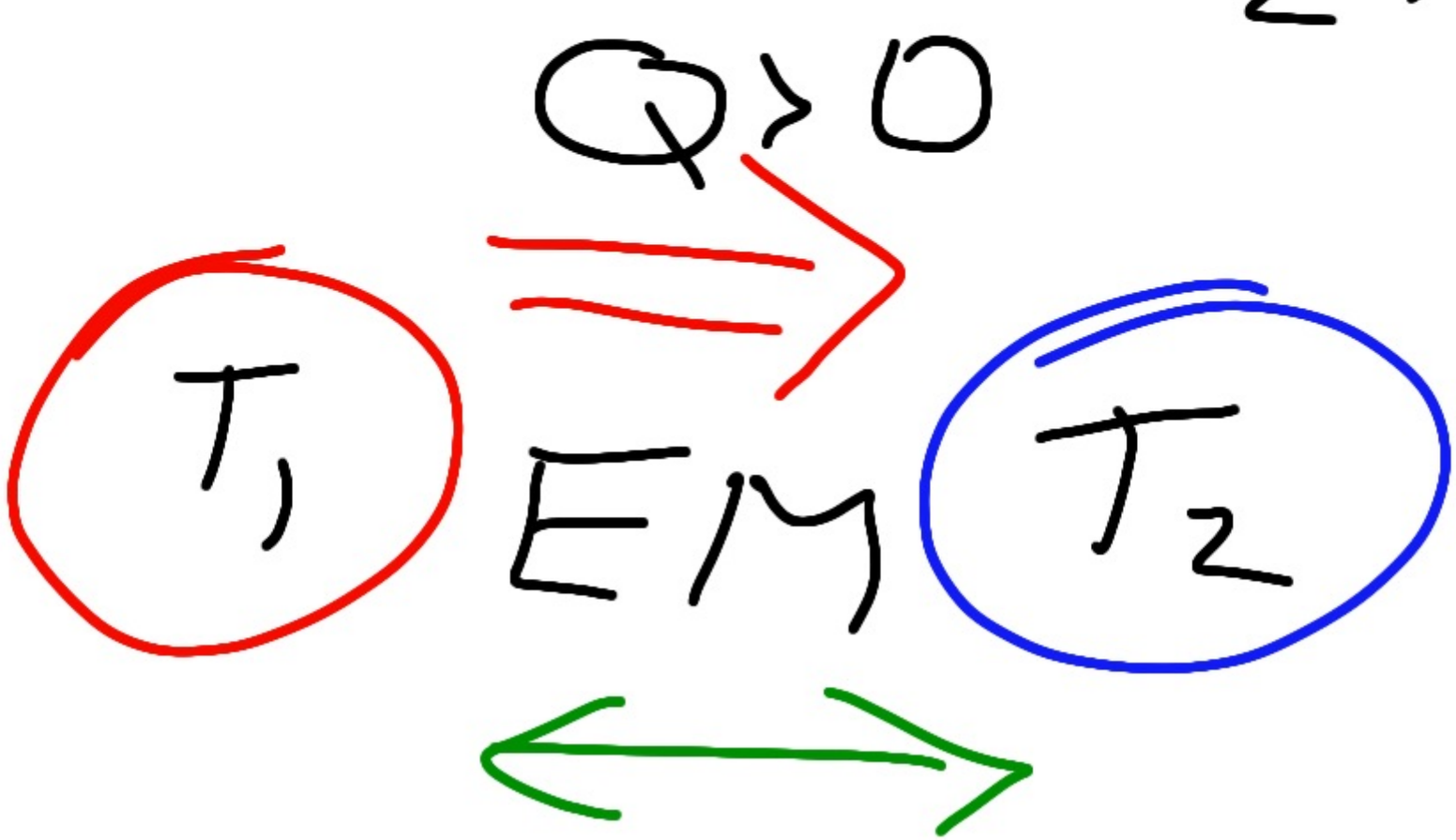
Max Planck 1900



Max Planck: The whole procedure was an act of despair because a theoretical interpretation (of black-body radiation) had to be found at any price, no matter how high that might be…I was ready to sacrifice any of my previous convictions about physics..For this reason, on the very first day when I formulated this law, I began to devote myself to the task of investing it with true physical meaning.

Planck's Radiation Law 1900

$$Q = \sigma(T_1^4 - T_2^4)$$



Non-Physical (Unstable) Version

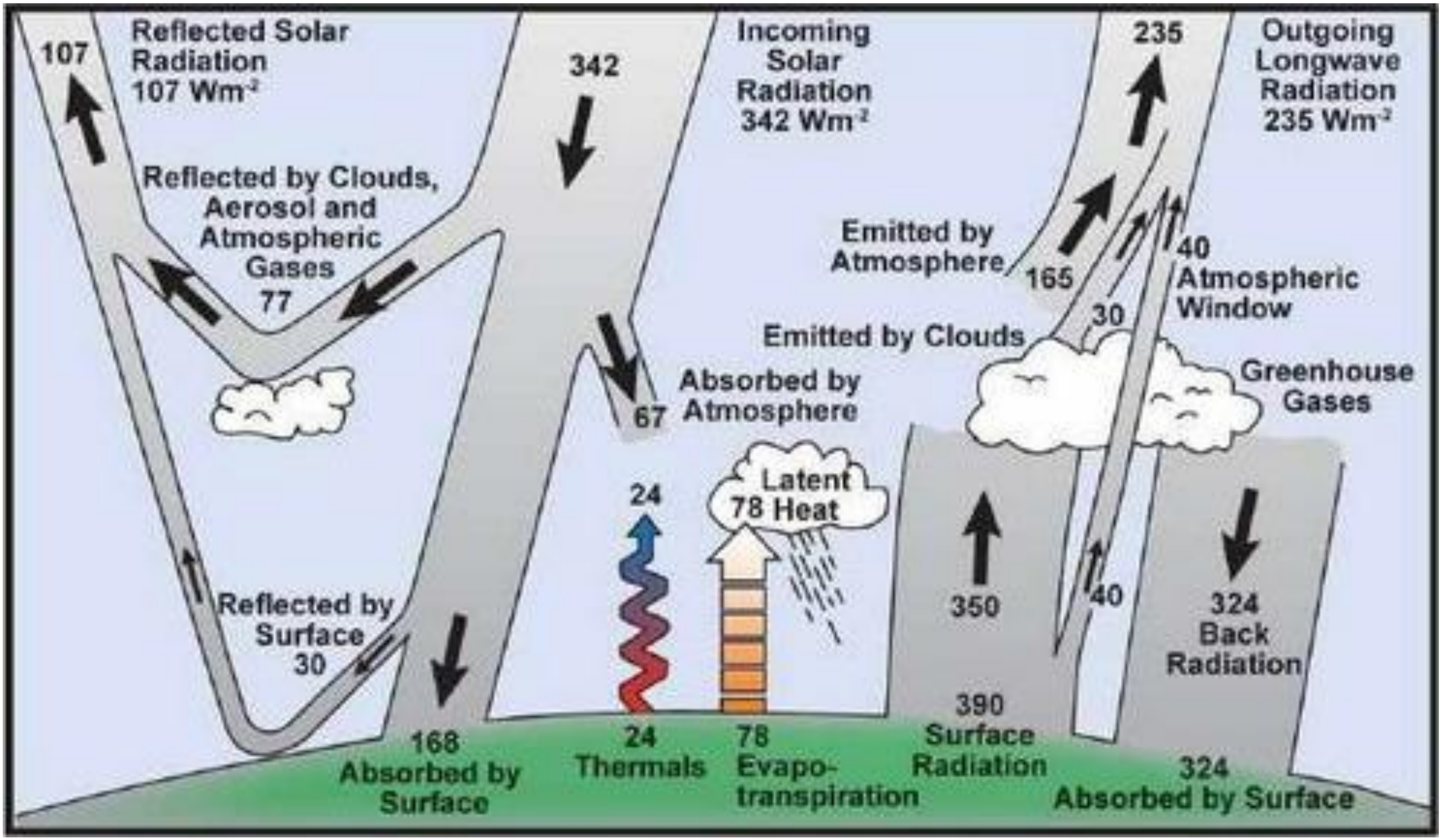
$$Q = \sigma(T_1^4 - T_2^4)$$

ONE WAY!

$$Q \neq \sigma T_1^4 - \sigma T_2^4$$

TWO-WAY: NON-PHYS

Backradiation Energy Budget: Global Warming



Proof of Planck's Law?

Planck's proof:

Statistics of Quanta: Ad hoc:
Invented Non-Real Physics
Microscopics of Microscopics

New proof:

Finite Precision Computation:
Constructive Real Physics

Radiative Heat Transfer by Maxwell's Equations

- **Two-way wave propagation**
- **One-way heat transfer warm-to-cold**
- **One-way by high-frequency cutoff**
- **No backradiation**
- **No two-way exchange of infrared photons**
- **Danger of misunderstanding Math!!**

Near-Resonance at Small Damping γ

u_tt - u_xx - γ u_ttt = f(x,t) ElectroMagn

u_tt - u_xx + γ u_t= f(x,t) Acoustics

ResonatingBody + Damping/Output= Forcing/Input

Efficiency = Output/Input = γu_t^2/f^2= 1

f out-of-phase with u_t: Output = Input

Balance: γ u_t << f γ^1/2 u_t = f

Near-Resonance:PianoTuning

- **Three Strings - One Note: 1 - 5 Hz Variation**
- **Slightly Mistuned: Loud - Too Loud: Eff = 1**

Two ways of push-pull swing

1. push-pull-pull-push: forcing in-phase with velocity:
Damping balances Forcing: u large

2. push-push-pull-pull: forcing out-of-phase with forcing
Residual of Resonating Body balances Forcing: u moderate

Guitar: Body-String-Output Sound: Efficient

High-frequency cut-off ~ Temp

Output = Input for frequency < cut-off: No Heating

Output < Input for frequency > cut-off: Heating

Heating of cold by warm.
One-way heat transfer, two-way wave propagation

Finite precision computation proof of Planck's Law
No Statistics as in Planck's 1900 proof

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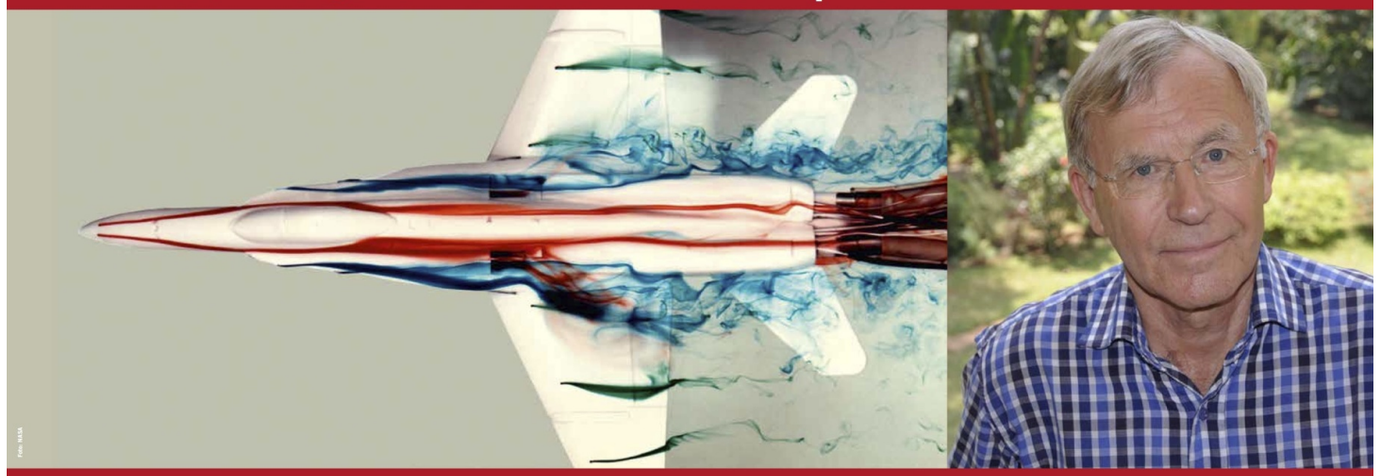
Interdisciplinary Center for Scientific Computing

HGS MathComp

UNIVERSITÄT HEIDELBERG
ZUKUNFT SEIT 1386

IWR-COLLOQUIUM / HGS MathComp von Neumann Lecture



The Secret of Flight

Fem-Simulation of Turbulent Flow

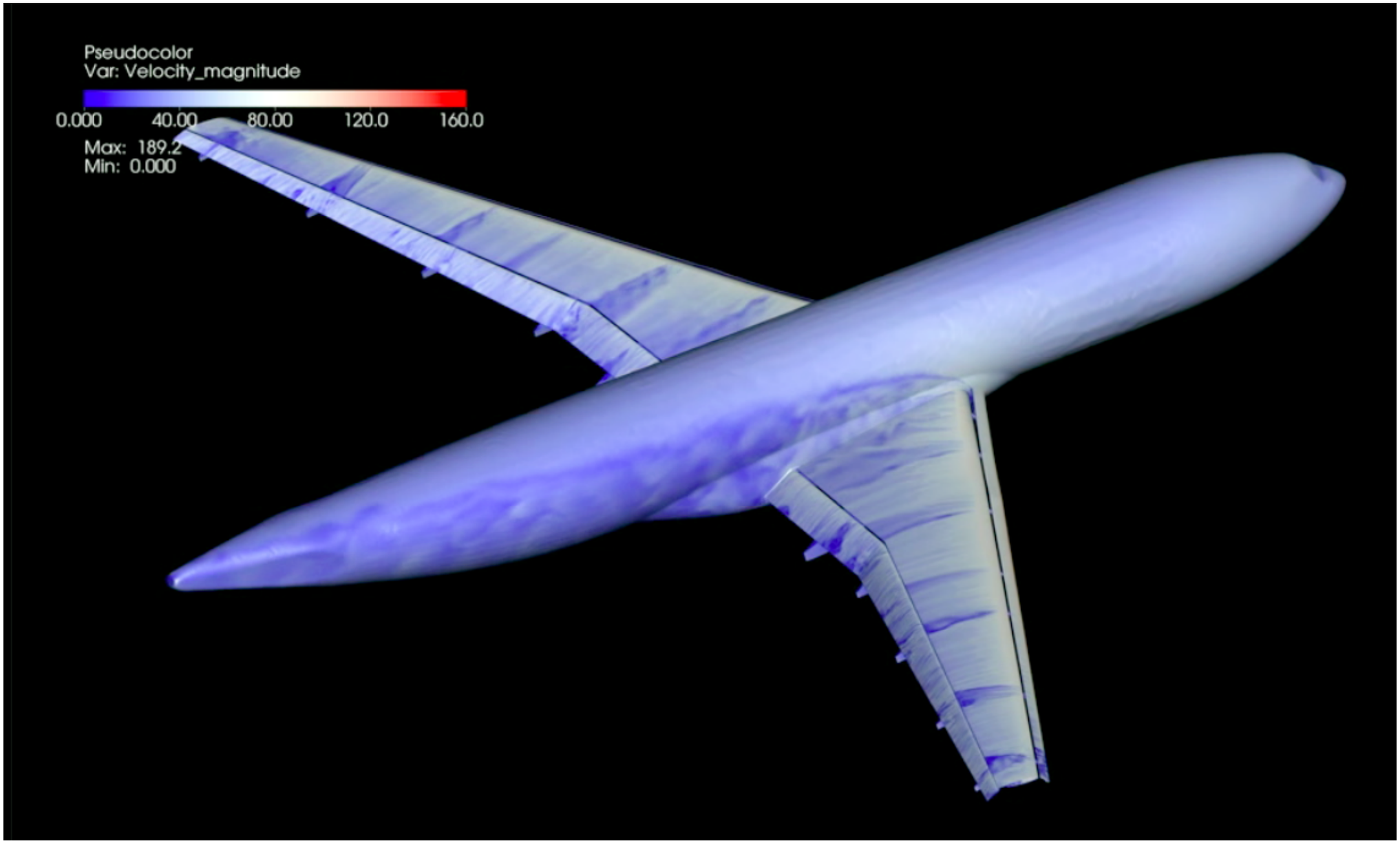
Prof. C. Johnson Royal Institute of Technology / Stockholm

We simulate slightly viscous turbulent low Mach number 3d bluff body flow (including streamlined bodies) by computational solution of the incompressible Navier-Stokes equations with a slip boundary condition modeling observed small skin friction, by using a residual stabilized adaptive finite element method, referred to as Direct Fem-Simulation since no turbulence model beyond automatic residual stabilization is used. We find by duality based a posteriori estimation that mean value quantities such as drag and lift are computable to accuracies comparable to experiments.

As a key example, we show that the turbulent flow around a complete airplane is computable and inspecting solutions leads to a new theory of flight essentially different from the accepted theory by Kutta-Zhukovsky-Prandtl developed 100 years ago. We find that turbulent bluff body flow in general can be described as potential flow modified by rotational slip separation as a flow which is resolvable computationally using millions of mesh points, except in a far-field wake of little influence on lift and drag, and also is understandable through a mathematical stability analysis.

December 4, 2013 · 5.15 pm
IWR · INF 368 · Room 432

NS/slip: First True Physical Simulation of Landing Jumbojet



New Theory of Flight

Textbook Theory: Kutta-Zhukovsky-Prandtl 1904: Non-Physical-Incorrect

Hoffman-Johnson 2008: Navier-Stokes/Slip: Physical-Correct

HighReynolds Bluff Body Flow

= Potential Flow + 3D Rotational Slip Separation

Thermodynamics: Compressible NS

2nd Law in terms of

Heat Energy - Kinetic Energy - Turbulent Dissipation

by Finite Precision Computation (No Statistics!)

Physical - Computable - Understandable

Compare with your own version of 2nd Law: Understandable??

Summary of 50 Years:

Computational Mathematical FEM Revolution:

From Slide Rule to Angry Birds and Turbulence

Math-Science-Education

Good Students - Coworkers - Friendly Collegues

Next: Real IT Revolution: Kurzweil Singularity:

Universal Computational Simulation: The Matrix

THANK YOU!!
All of You!!