Kevin Heng, Theoretical Astrophysicist

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CSH
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Born: Singapore
Married to German (+ 2 German boys)
Swiss permanent residency

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Research interests: exoplanets, planetary science, epidemiology
[5 postdocs, 4 Ph.D students, 1 Master student]

Professor of Astrophysics (tenured), University of Bern, Switzerland (2015-present)
Executive Director, Center for Space & Habitability (2016-present)
Honorary Professor, University of Warwick, U.K. (2020-present)

Tenure-track Assistant Professor, University of Bern, Switzerland (2013-2015)
Zwicky Prize Fellow, ETH Zurich, Switzerland (2010-2012)
Frank & Peggy Taplin Member, Institute for Advanced Study, Princeton (2009-2010)
Member, Institute for Advanced Study, Princeton (2007-2009)
Ph.D, Astrophysics, University of Colorado (2007)
M.S., Astrophysics, University of Colorado (2005)
B.Sc (Hons), Physics, National University of Singapore (2003)
Military Service (1996-1999)
Serangoon Junior College (1995-1996)

The oldest question ever asked by humanity

Are We Alone?

Prof. Dr. Kevin Heng
CSH Director

How do we scan the heavens to find out?

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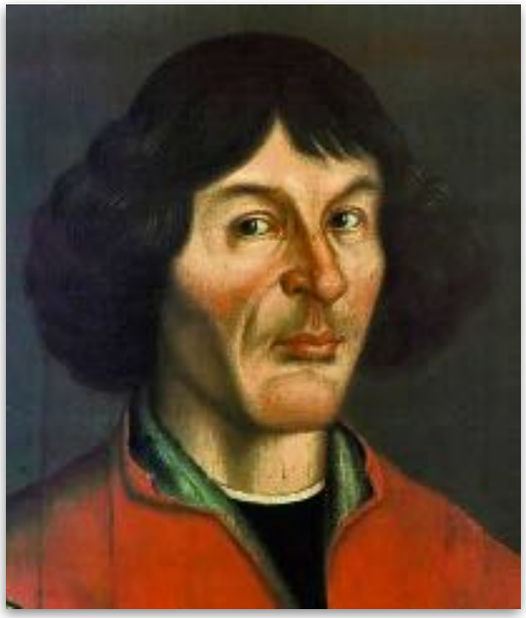
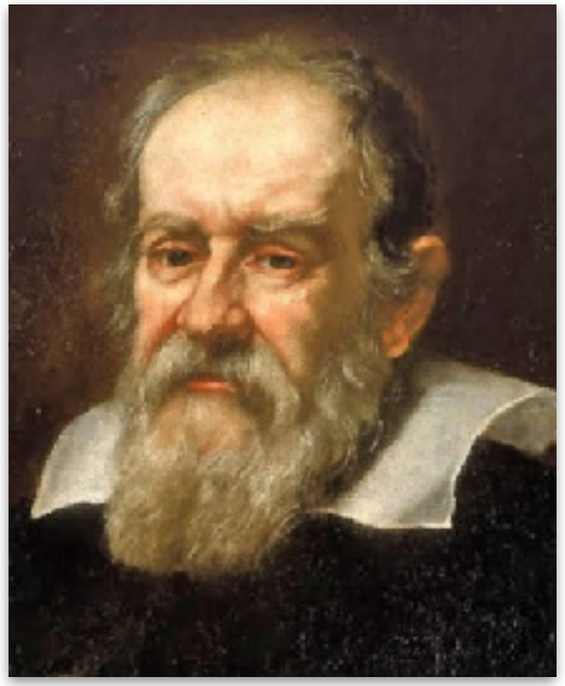
Questioning the uniqueness of Earth was heresy in antiquity

Giordano Bruno
(1548 - 1600)



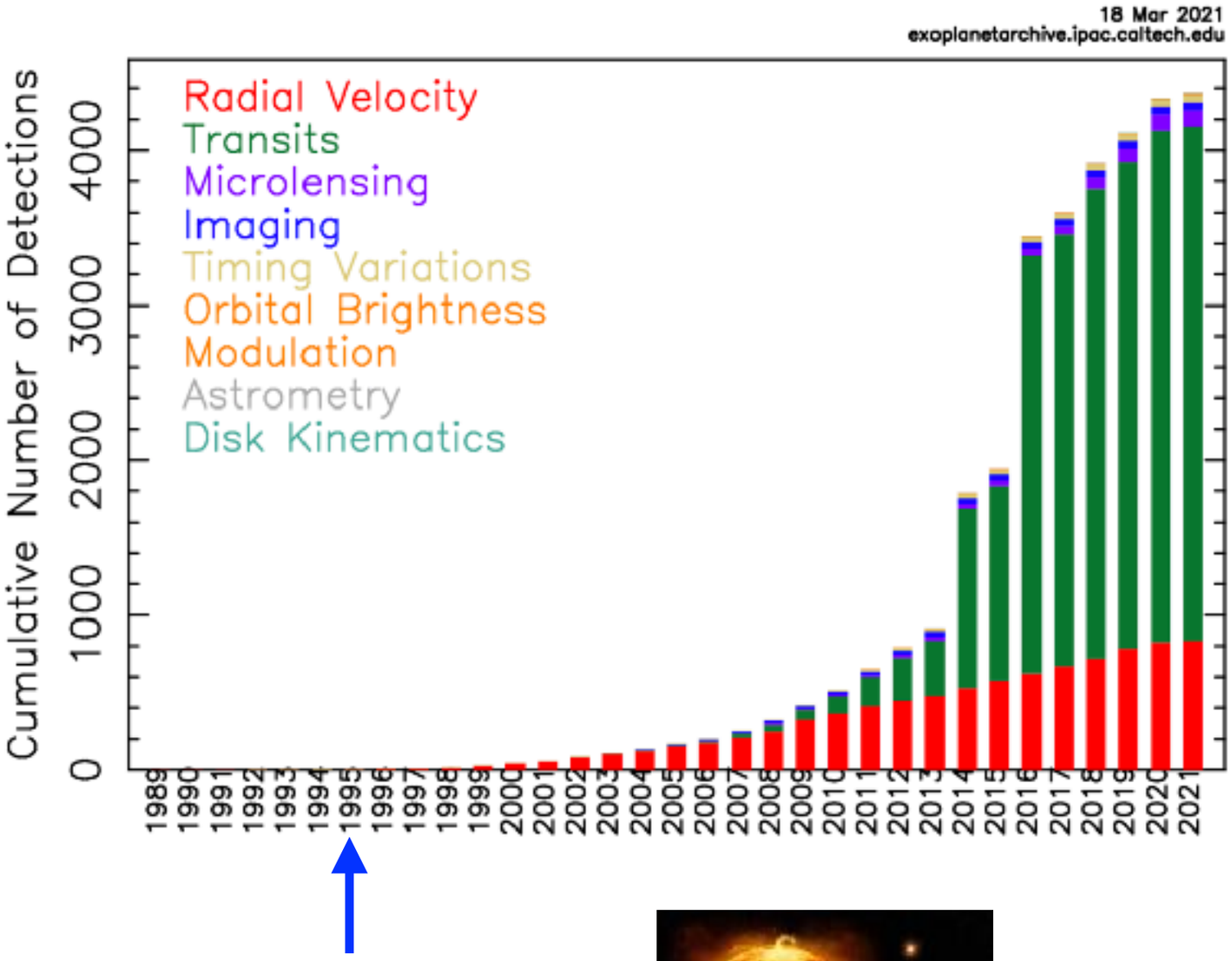
Nicolaus Copernicus
(1473 - 1543)



Galileo Galilei
(1564 - 1642)

"There are countless Suns and countless Earths all rotating around their Suns in exactly the same way as the planets of our system."

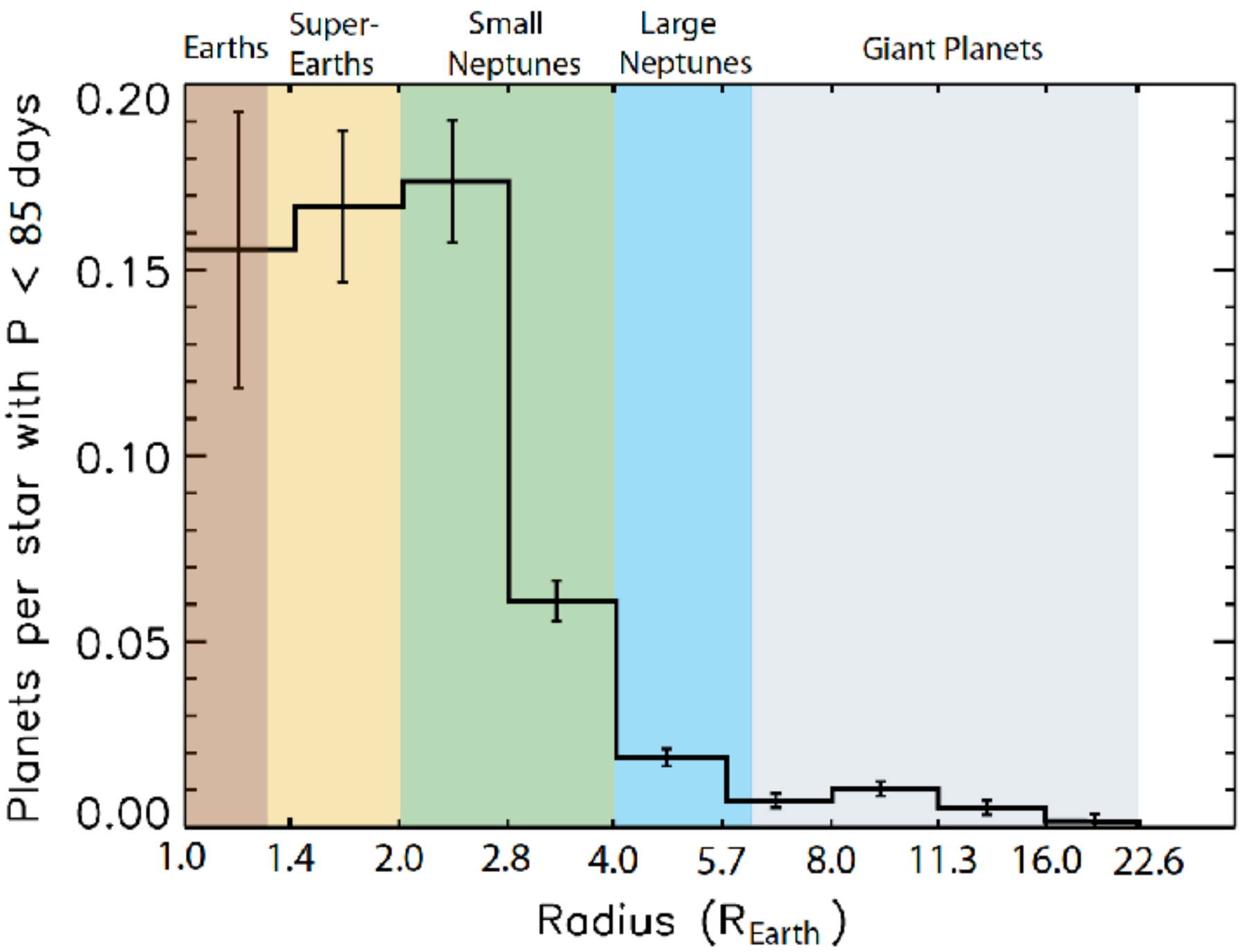
An exoplanet is a planet orbiting another star, beyond our Solar System



Discovery of first exoplanet around Sun-like star
(Mayor & Queloz 1995)

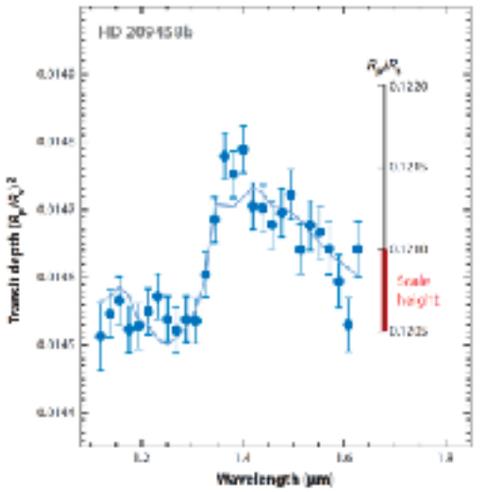
2019 Nobel Prize in Physics
Michel Mayor (Geneva)
Didier Queloz (Cambridge/Geneva)

A major surprise: exoplanets between the sizes of Earth and Neptune are common



Fressin et al. (2013, ApJ, 766, 81)

Studying exoplanets using telescopes



Hubble Space Telescope

Current workhorse for detecting
water in atmospheres of exoplanets

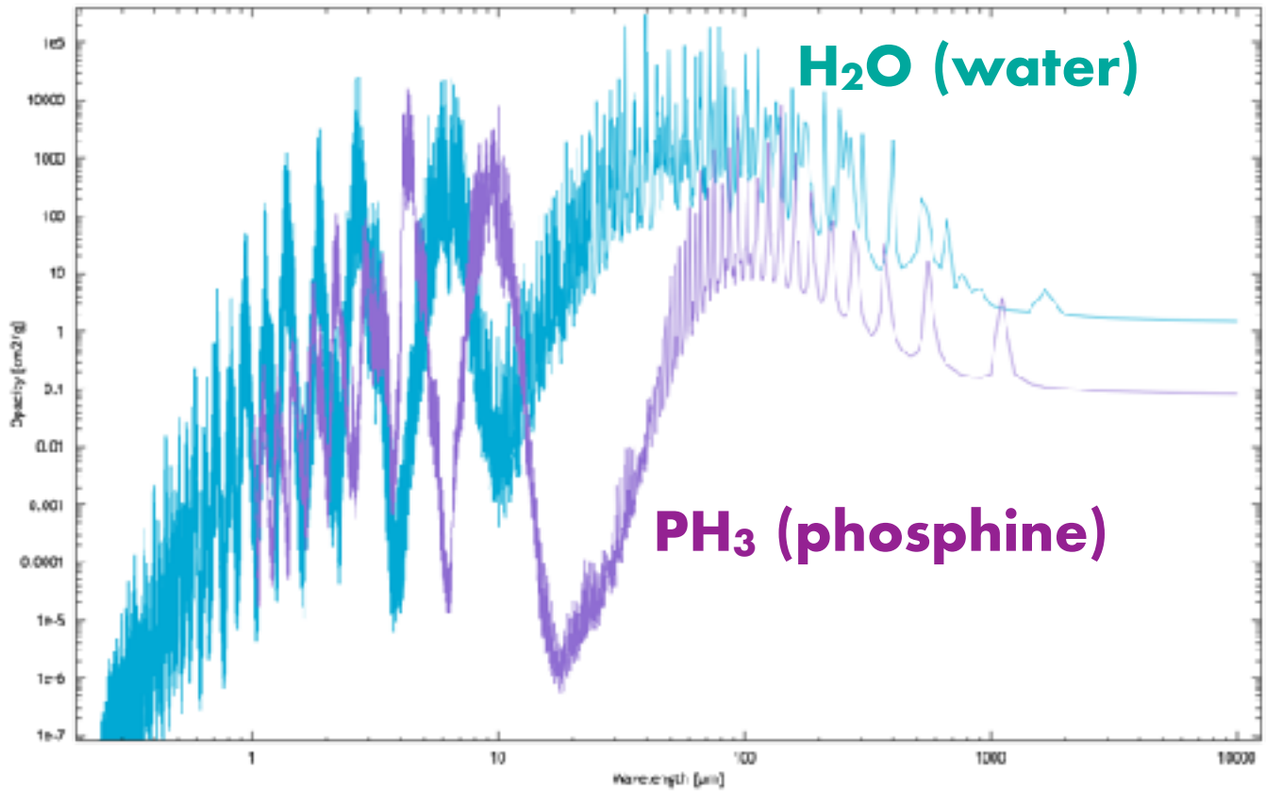
James Webb Space Telescope

6.5 meter (gold) mirror
optical to mid-infrared spectroscopy
USD 10 billion mission (launch: 2021)

Extremely Large Telescope

first light: 2025
39 meter mirror
high-resolution spectroscopy

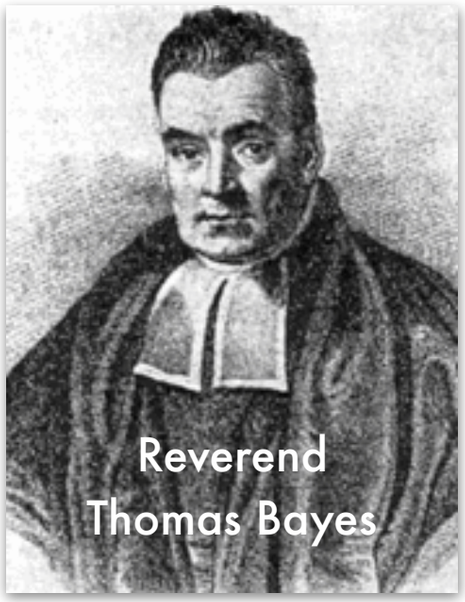
The hunt for biosignatures



dace.unige.ch

1. Gas
2. Associated with biochemistry
3. Not geological false positive
4. Accumulates in atmosphere
5. Stable over geological time scales
6. Spectrally distinguishable from major greenhouse gases

Tools of the trade



Bayesian statistics & inference

How do I interpret data using a family of models?

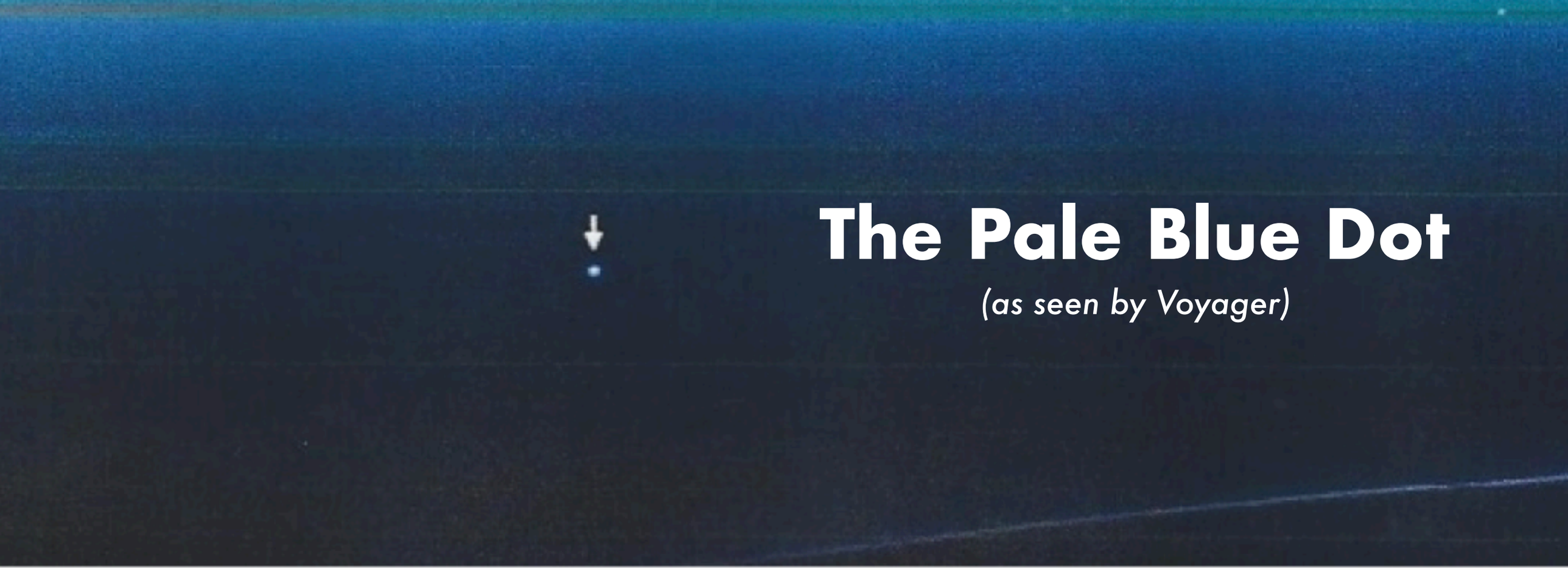
What is the simplest model given the quality of the data (Occam's Razor)?

Atmospheric physics and chemistry + geochemistry

Machine learning

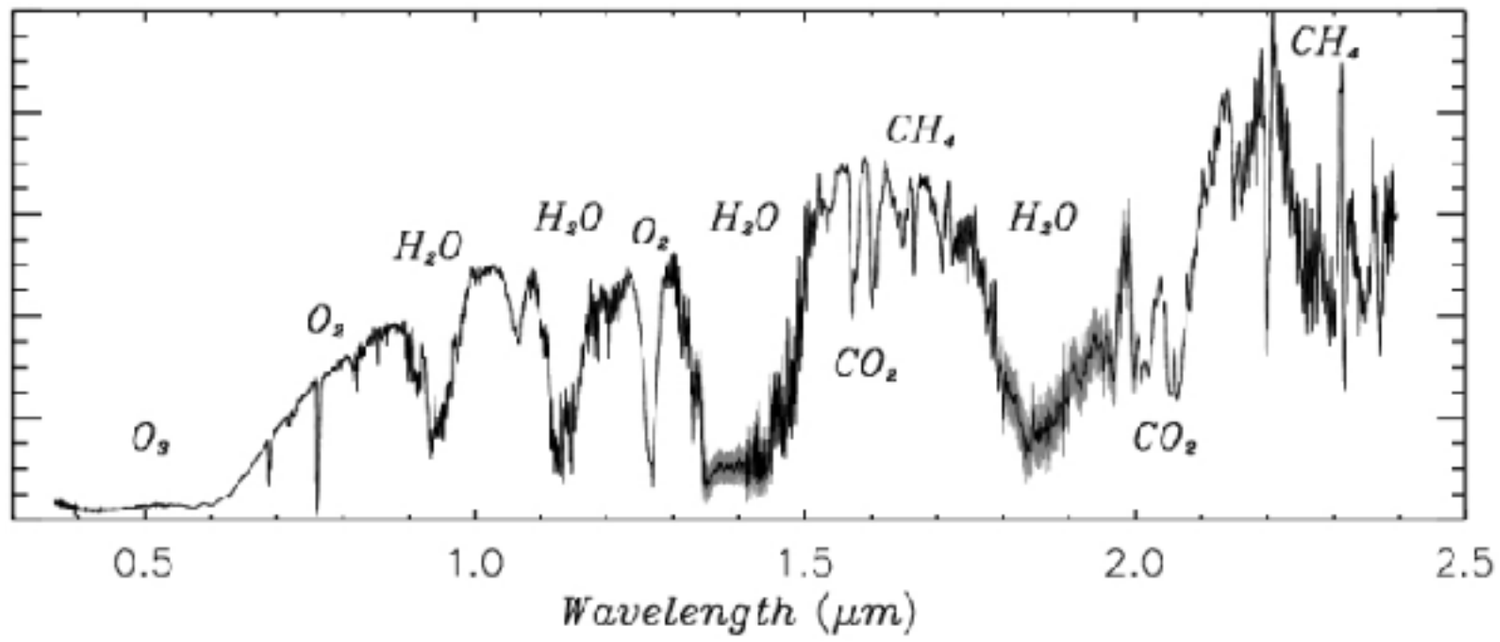
Searching for biosignatures ⟶ pattern recognition problem

May we perform Bayesian inference with machine learning?



The Pale Blue Dot

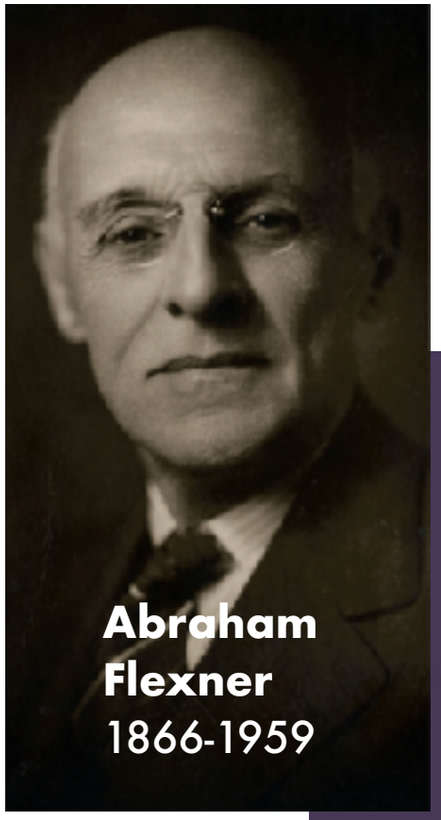
(as seen by Voyager)



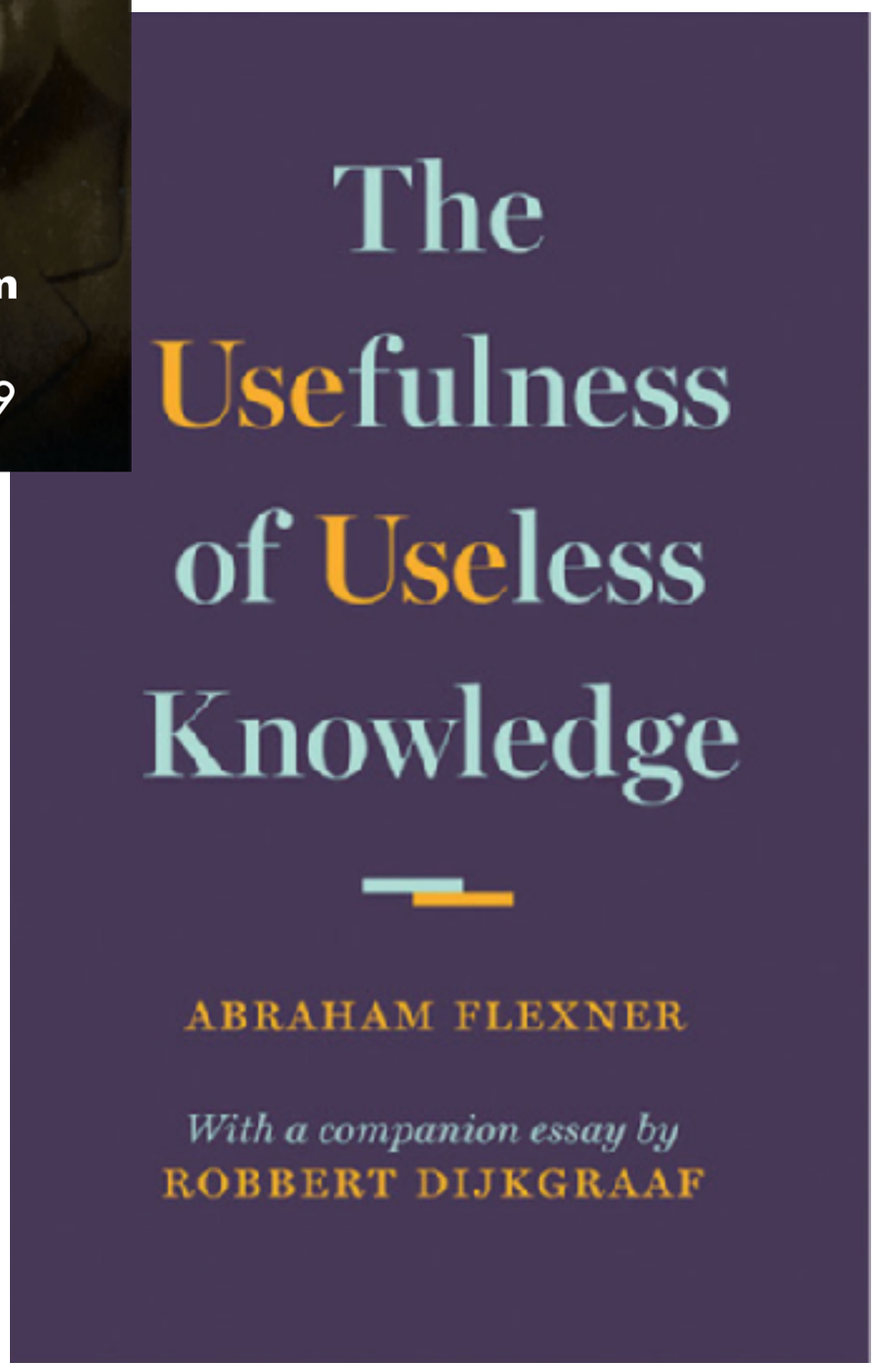
Spectrum from Palle et al. (2009, Nature, 459, 814)

What's the value of "blue sky" research?

(curiosity-driven)



Abraham Flexner
1866-1959



Abraham Flexner: Jewish-American pioneer of education reform

1910 "Flexner Report" led to modern age of biomedical research and teaching

First director of Institute for Advanced Study (IAS), Princeton

Hired Einstein, von Neumann, etc, as faculty

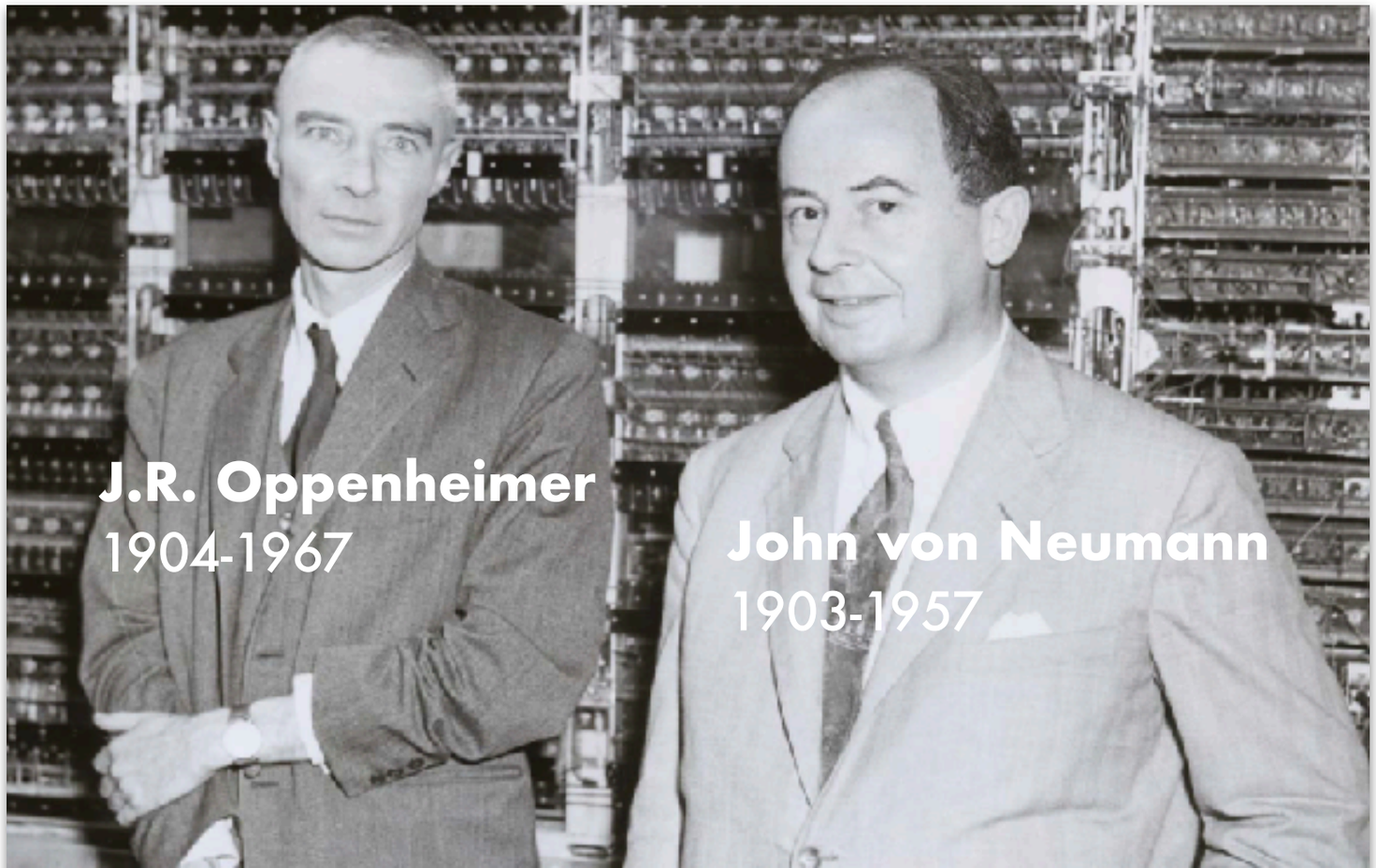
Vision:
"unobstructed pursuit of useless knowledge"

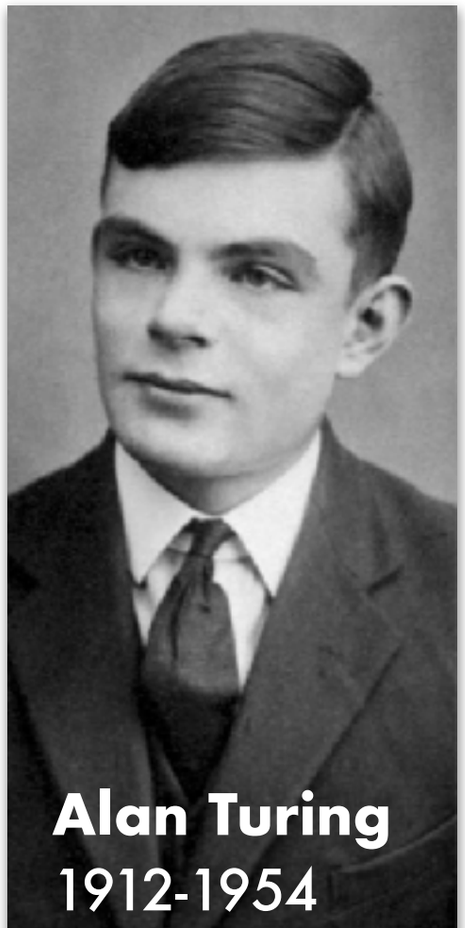
Turing machines, bombs and weather prediction

Turing imagined an abstract device capable of manipulating symbols on an “infinite tape” according to mathematical rules

Fascinated by Turing’s ideas, von Neumann built one of the world’s first computers at the IAS

Used for numerical simulations of bombs and weather prediction





Examples of “useless knowledge” and implications

- Quantum mechanics (once called *“Knabenphysik”*):
  microprocessors, lasers, nanotechnology, etc

- General relativity: global positioning system (GPS)

- Information sharing system by CERN physicists: internet

- Paul Ehrlich’s curiosity-driven “fooling” (*“Ich probiere”*):
  invention of bacteria staining and bacteriology

- Image analysis in astronomy:
  invention of IDL programming language

- Pattern classification and recognition:
  machine learning, full societal implications still unknown

George Porter (Nobel laureate in chemistry):
"applied" versus "not-yet-applied" research

Predictable,
stable,
short-term bets
("useful research")

Risky,
speculative,
long-term bets
("useless research")

Society should view research as a balanced portfolio of investments

Some examples from my own research sphere

Collaboration with medical imaging experts (computer scientists)**:**

- Cancer and biosignature identification are conceptually similar in the context of machine learning (neural networks).
- Remote sensing technique of circular polarisation may be used to diagnose brain cancer non-invasively (cf. Prof. B.-O. Demory).

Collaboration with epidemiologists:

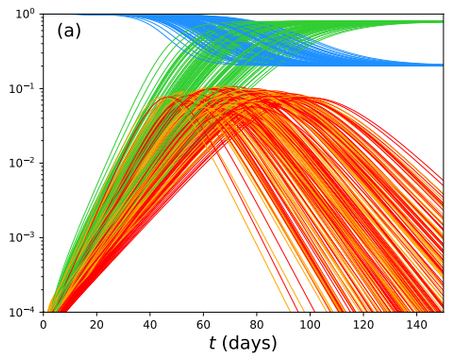
- Compartmental models of epidemiology share similar equations to those of atmospheric chemical kinetics.

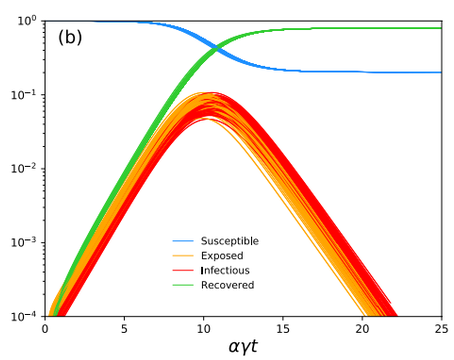
Article | Open Access | Published: 09 November 2020

The approximately universal shapes of epidemic curves in the Susceptible-Exposed-Infectious-Recovered (SEIR) model

Kevin Heng ✉ & Christian L. Althaus

Scientific Reports **10**, Article number: 19365 (2020) | Cite this article





"In the beginner's mind there are many possibilities, in the expert's mind there are few."

– Shunryu Suzuki