Prediction: Week 12

SPACE FUTURES

From Fear to Landings: Comets

The 3-body problem | n-body simulation | Illustris (+more physics)

Avi Loeb | *Astronomy Simulation (with expert TFs)*

Jill Tarter | Extraterrestrials & the Drake equation

Special guest behavioral economist (Federico Slepoi)

SPACE FUTURES discussions

From Fear to Landings: Comets

Avi Loeb, Astrophysicist

INTERACTIVE VIDEO
PredictionX
Prediction in Astrophysics

Watch clip

#avi_loeb

00:02:06

How do astrophysical simulations work?

Watch clip | Learn more

#astrophysical_simulation #model_inputs

00:04:11

Dark matter and dark energy create uncertainty in our predictions for future astrophysical activity.

Watch clip | Learn more

#dark_matter #dark_energy #uncertainty #predictability

00:04:51

Using our comprehension of physical laws and observations of light from billions of light years away (in the past), we can utilize simulations to do space archeology to recreate the history of the universe.

Watch clip | Learn more

#space_archeology #history_of_the_universe #galactic_evolution

00:06:24

The origins of life on Earth, and the implications on our estimates of the probability of extraterrestrial life

+ Loeb's strong opinions about AI:

If studies don't lead to deep understanding, we can't build on them (so they're not worth doing…for him?)

Astronomy Simulation (with expert TFs)

Padua Rainbow for the theory of galaxy evolution

Phenomenon	Observation*	Data	Rule	Theory	Explanation	Prediction

. Images in different wavelength
. Spectra

Local galaxies

Simulation is used to apply:
- Known physics theory (i.e. gravity, hydrodynamics, etc)
- Empirical correlation
- Analytical theory

(see Mila's presentation)

Pipit Triani

Dr. Pipit Triani's Slides

The **same principles**, applied to not just stars but also gas and dark matter, **allow us to understand the evolution of the entire Universe** over billions of years

Mila Chadayammuri

Dr. Mila Chadayammuri's Slides

Jill Tarter, SETI expert

INTERACTIVE VIDEO
PREDICTIONX
THE SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE

1. The Search for Extraterrestrial Intelligence

00:26:06

What can we predict about humanity's response to first contact with extraterrestrial civilization? Will we come in peace, will they?

Watch clip | Learn more

#human_response #arrival #first_contact #aliens

00:30:08

Why the Search for Extraterrestrial Intelligence is no longer government-funded.

Watch clip

#fear #government_and_aliens

00:34:01

What is the future of manned space flight? Will it be us or robots who explore space?

+ Tarter's question for aliens (as in CONTACT):
How did you make it through this technological adolescence?

Federico Slepoi, Behavioral Economist

ROMA

Federico Raimondi Slepoi

Roma Capitale
R^2 - Ufficio di Scopo Innovazione per le Politiche Comportamentali

From Fear to Landings: Comets

The Path to Newton

PREVAILING BELIEF

CONCERNED WITH PHENOMENA

EARTH AT CENTER (⊙ BELIEVED SUN AT CENTER)

TOOLS AVAILABLE

GNOMON

GNOMON

ASTRO

MATH AVAILABLE

ARITHMETIC & ACCOUNTING
ZERO AS PLACE HOLDER
PLANAR GEOMETRY

ARITHMETIC
ZERO AS PLACE HOLDER
PLANAR GEOMETRY
SPHERICAL GEOMETRY

ARITHMETIC
ZERO AS PLACE HOLDER
PLANAR GEOMETRY
SPHERICAL GEOMETRY
TRIGONOMETRY

SPRERICAL TRIGONOMETRY

BIG IDEAS

Correct

Partial credit

Wrong

CONNECTIONS BETWEEN IDEAS

Teacher-Pupil or Senior-Junior Researcher

Travel between cultures

Published works

Hey, the cycles in the sky repeat. Let's track them.

BABYLONIANS
c. 2000–300 BCE

Astronomical Diaries

Some "stars" move more than others

Natural, not supernatural.

THALES
624–546 BCE
Greek

Nature can be explained

Motion needs a little push.

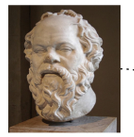
ANAXAGOROS
510–428 BCE
Greek

Motion must have a cause

Motion and change are illusions

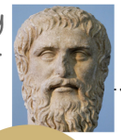
Question all you "see."

PARMENIDES
515–450 BCE
Greek



SOCRATES
470–399 BCE
Greek

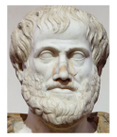
PLATO
427–347 BCE
Greek



Symmetry rules.

The air moves objects through it

Rearranging "atoms" allows motion



Circles spheres, beauty, eternity...

ARISTOTLE
383–322 BCE
Greek

...oh, and you're so wrong about motion, Plato.

All things move to their natural place

Earth is stationary center of the universe

Planets, Moon, Sun, move on spheres

It's spheres all the way down.

EUDOXUS
390-337 BCE
Greek

STUFF on Earth and in the Heavens is all the same... just atoms.

DEMOCRITUS
460–370 BCE
Greek

The universe is WAY bigger than you might think.

ANAXIMANDER
610–546 BCE
Greek

Earth generated by boundless eternity

Universe is spherical

If circles are perfect, spheres are sublime.

PYTHAGORAS
570–495 BCE
Greek

I can prove it!

EUCLID
300? BCE
Greek

A single framework for all geometry

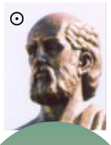
Elements
Euclid
c. 300 BCE

Circles ARE the best! We just need more!

PTOLEMY
100–170
Greek living in Roman Egypt

Epicycles, equants, eccentrics

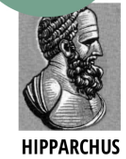
The Almagest
Ptolemy
c. 150



Hello? Is this thing on?

ARISTARCHUS
310–230 BCE
Greek

Sun at center



I'm not sure Earth is exactly in the center?

HIPPARCHUS
190-120 BCE
Greek living in Rome

Math can model the universe

With one little function, I'll give you the Moon!

On the Heavens
Aristotle
c. 350 BCE

Physics
Aristotle
c. 320 BCE

SUN AT CENT

GNOMON
ASTROLABE

ARITHMETIC
ZERO AS PLACE HOLDER
PLANAR GEOMETRY
SPHERICAL GEOMETRY
TRIGONOMETRY
SPRERICAL TRIGONOMETRY
SPHERICAL TRIGONOMETRY
ALGEBRA

ZERO AS NUMERAL

ARITHMETIC
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ALGEBRA
TUSI COUPLE AND OTHER SPECIAL FORMS

Motion caused by self-exhausting force

Celestial and terrestrial phenomena similar

Aristotle is wrong about space, time, and matter.

JOHN PHILOPONUS
490–570
Greek living in Roman Egypt

Circles ARE the best! We just need more!

PTOLEMY
100–170
Greek living in Roman Egypt

I must gather more information for better astrology, and I shall share what I learn!

VĀRĀHAMIHIRA
505–587
Indian

Epicycles, equants, eccentrics

With one little function, I'll give you the Moon!

ARYABHATA
476–550
Indian

Sines improve accuracy

I'm not sure Earth is exactly in the center?

PARCHUS
-120 BCE
ek living
Rome

Who knew nothing could be so useful?

BRAHMAGUPTA
598–668
Indian

Zero is a numeral unto itself

Accuracy is key (e.g., 365.24 days in a year)

Years from now, Copernicus will love me.

AL-BATTANI
858–929
Arab

It just keeps going, and going... but not really.

IBN SINA (AVICENNA)
980–1037
Persian

Motion is indefinite without external forces

Metaphysics? Hooey! Give me evidence and math.

IBN AL-HAYTHAM
965–1040
Arab

Models matching data is paramount

If I use a teeny unit of time...

BHĀSKARA II
1114–1185
Indian

Much of what we today call calculus

What did Aristotle really mean? We need to question.

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Motion is a chain of an object's locations

Bigger observatories, better observations.

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Motion explained with "impetus theory"

Simple circular orbits work with better math

This is math, not philosophy.

JEAN BURIDAN
1295–1358
French

The Earth might actually rotate

Earth need not be at rest, Ptolemy!

ALI QUSHJI
1403–1474
Turkic

Come on! You can't "give" an object motion.

NICOLE ORESME
1320–1382
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Objects are "set into" motion

Math first, philosophy later.

NICHOLAS COPERNICUS
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Polish

Sun at center of Earth's & planets' orbits

I can improve Ptolemy! To the printing press!

REGIOMONTANUS
1436–1476
German

The Almagest
Ptolemy
c. 150

Aryabhatiya
Aryabhata
c. 499

On Aristotle's Physics 3
Philoponus
c. 520

Pañca-siddhāntikā
Vārāhamihira
c. 575

Brahmasphuta-siddhanta
Brahmagupta
c. 628

TRANSLATION MOVEMENT WORKS

Kitāb az-Zīj
al-Battani
c. 900

Kitāb al-Shifa'
Ibn Sīnā
c. 1020

Al-Shukūk 'alā Batlamyūs
Ibn al-Haytham
c. 1025

Siddhānta Shiromani
Bhāskara II
c. 1150

Commentaries on Aristotle
Ibn Rushd
c. 1150-1200

Alfonsine Tables
1252

Al-Tadhkirah fi'ilm al-hay'ah
al-Tusi
1261

Epitome of the Almagest
Regiomontanus
1496

De Revolutionibus
Copernicus
1543

Comets in Ancient Times

(with Owen Gingerich & Sara Schechner)

Scrovegni Chapel,
Padua, Italy

Comets in the Middle Ages

Adoration of the Magi

Scrovegni Chapel,
Padua, Italy

Note the comet overhead in this Giotto fresco, painted in the early 1300s. The inspiration for the comet? Halley's Comet, which was visible from Earth in 1301-1302.

SUN AT CENT

GNOMON
ASTROLABE

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PREDICTIONX

SUN AT CENTER (⊕ BELIEVED EARTH AT CENTER)

GNOMON
ASTROLABE
PRINTING PRESS

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ALGEBRA
TUSI COUPLE AND OTHER SPECIAL FORMS

GNOMON
ASTROLABE
PRINTING PRESS
TELESCOPE

ARITHMETIC
ZERO AS NUMERAL RAL
PLANAR GEOMETRY
SPHERICAL GEOMETRY
TRIGONOMETRY
SPERHICAL TRIGONOMETRY
ALGEBRA
SPECIAL FORMS
LOGARITHMS

ARITHMETIC
ZERO AS NUMERAL
PLANAR GEOMETRY
SPHERICAL GEOMETRY
TRIGONOMETRY
SPHRERICAL TRIGONOMETRY
ALGEBRA
SPECIAL FORMS
LOGARITHMS
CALCULUS

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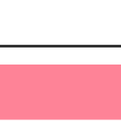

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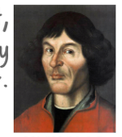

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1320–1382
French

Planets orbit the Sun, but Sun orbits Earth

TYCHO BRAHE
1546–1601
Danish

With giant spendy instruments, I can get GREAT data.

Jupiter has moons, which orbit like our Moon

JOHANNES KEPLER
1571–1630
German

I have Tycho's fancy data!

Hmm... circles are a problem.

Orbits are ellipses, not circles

Sun is the center

All bodies on Earth have (circular) inertia

All bodies have inertia

GALILEO GALILEI
1564–1642
Italian

Oooh, I like this Dutch spyglass!

Sorry, Aristotle, you're just wrong.

RENÉ DESCARTES
1596–1650
French

Aristotle, mon ami, above and below, it's all matter in motion.

GRAVITY GOVERNS ALL

ISAAC NEWTON
1642–1726
British

We're gonna need better math.

This apple. That moon. Could they feel the same pull?

EDMOND HALLEY
1656–1742
British

I must make Newton publish!

Some comets return, predictably

Commentaries on Aristotle
Ibn Rushd
c. 1150-1200

Alfonsine Tables
1252

Al-Tadhkirah fi'ilm al-hay'ah
al-Tusi
1261

Epitome of the Almagest
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De Revolutionibus
Copernicus
1543

Astronomia Nova
Johannes Kepler
1609

Siderius Nuncius
Galileo
1610

Dialogue on the Two Chief Systems of the World
Galileo
1632

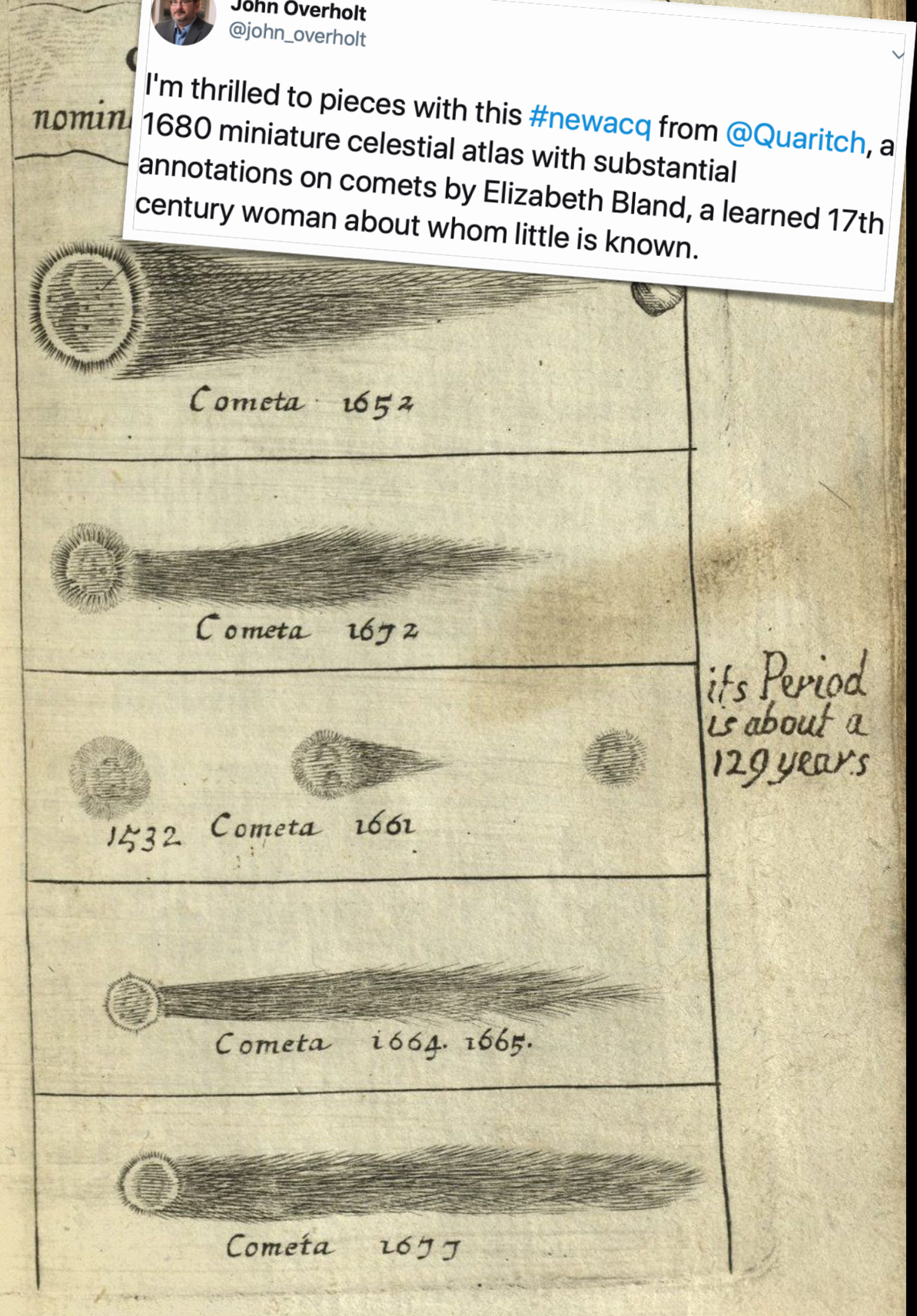
Two New Sciences
Galileo
1638

Principles of Philosophy
Descartes
1644

Principia
Isaac Newton
1687

Synopsis Astronomia Cometicae
Edmond Halley
1705

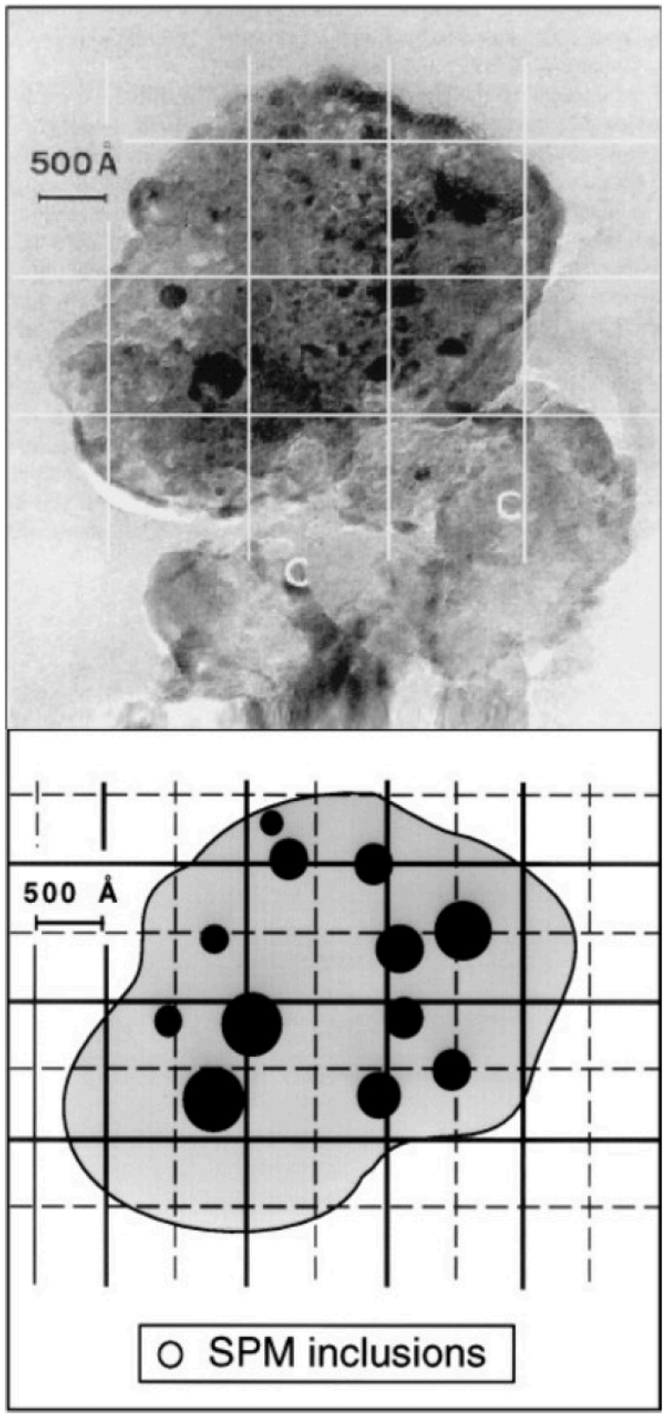
Comets in the Renaissance



Comets, Newton & Gravity(!)

(Simon Schaffer on the BBC, 2008)

Fig. 1. from A Point in Favor of the Superparamagnetic Grain Hypothesis
Goodman &
Whittet 1995 ApJL 455 L181 doi:10.1086/309840
http://dx.doi.org/10.1086/309840



Comets Today

we *navigate*
to them!

ROSETTA

12 years through space

Today: we use Newton's Laws to land on comets

ROSETTA

Today: we use Newton's Laws to land on comets

Astronomy Simulation & **SPACE FUTURES**

Avi Loeb, Astrophysicist

INTERACTIVE VIDEO
PredictionX
Prediction in Astrophysics

Watch clip

#avi_loeb

00:02:06

How do astrophysical simulations work?

Watch clip | Learn more

#astrophysical_simulation #model_inputs

00:04:11

Dark matter and dark energy create uncertainty in our predictions for future astrophysical activity.

Watch clip | Learn more

#dark_matter #dark_energy #uncertainty #predictability

00:04:51

Using our comprehension of physical laws and observations of light from billions of light years away (in the past), we can utilize simulations to do space archeology to recreate the history of the universe.

Watch clip | Learn more

#space_archeology #history_of_the_universe #galactic_evolution

00:06:24

The origins of life on Earth, and the implications on our estimates of the probability of extraterrestrial life

+ Loeb's strong opinions about AI:

If studies don't lead to deep understanding, we can't build on them (so they're not worth doing…for him?)

Astronomy Simulation & **SPACE FUTURES**

The 3-body problem	n-body simulation	Illustris (+more physics)

The 3-body problem

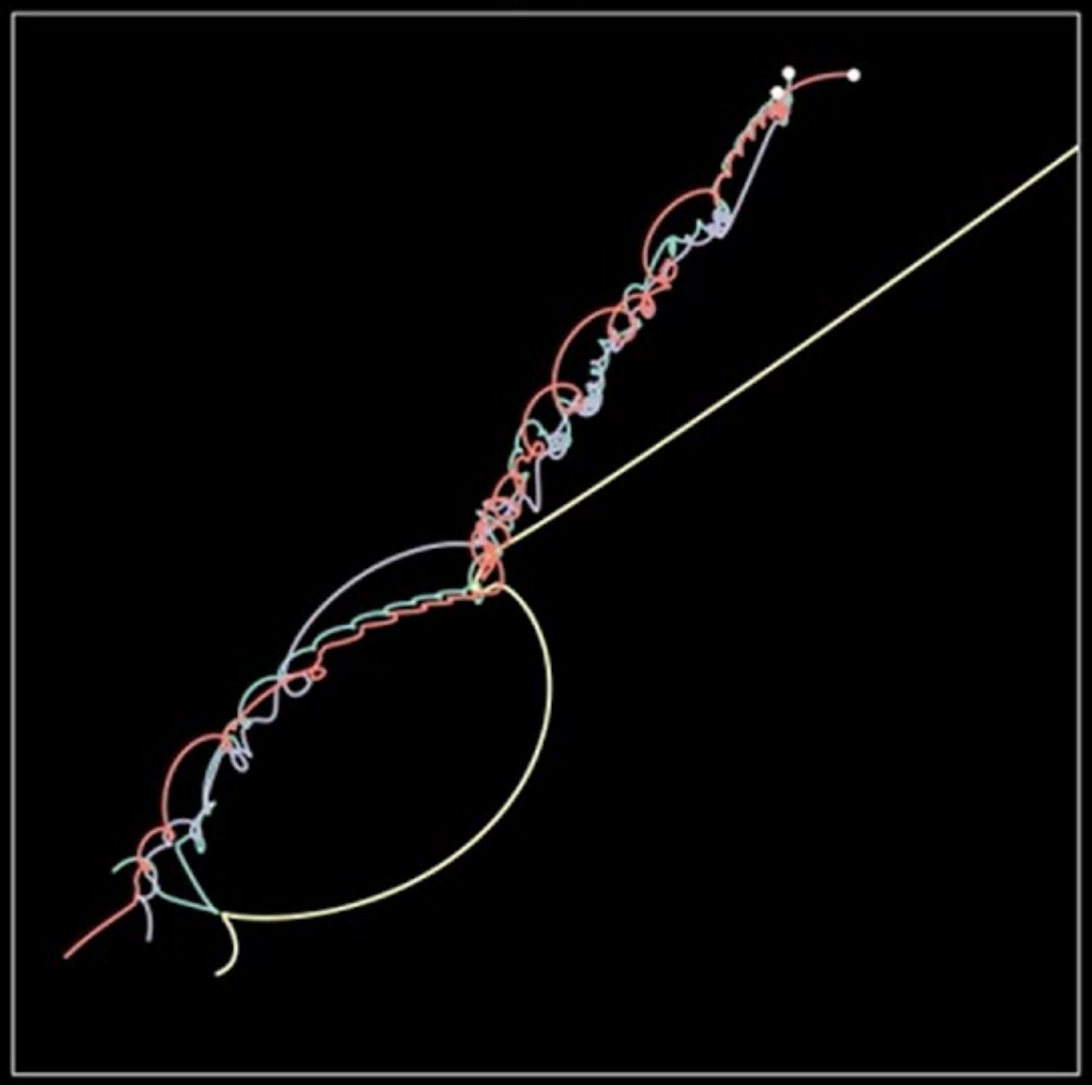
which Newton's Law of gravity alone cannot exactly solve

Note: good overview at: en.wikipedia.org/wiki/Three-body_problem

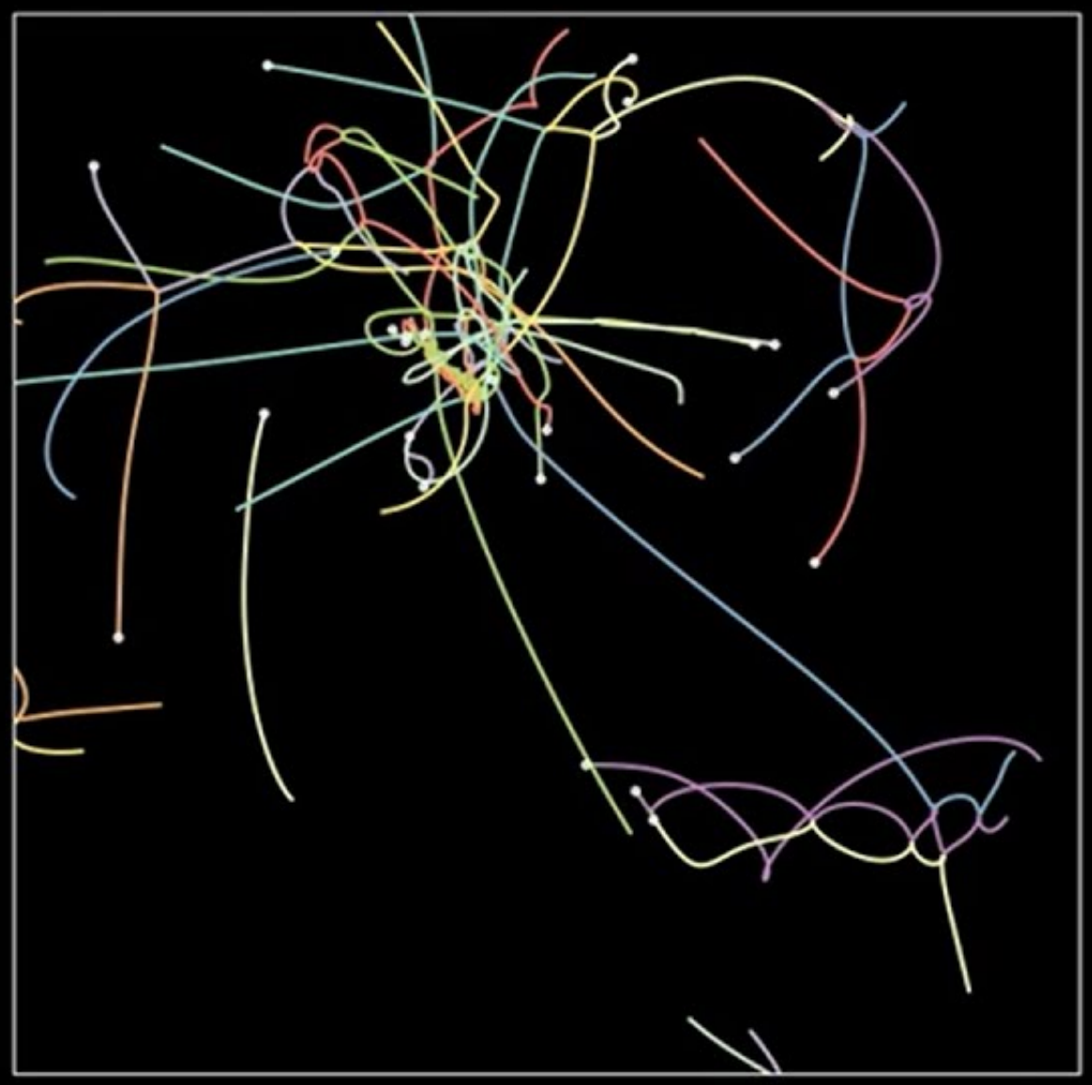
The 3-body problem

n-body simulation

N = 4



N = 30



N body simulation in Python with code (from “Simulating Physics” on YouTube)

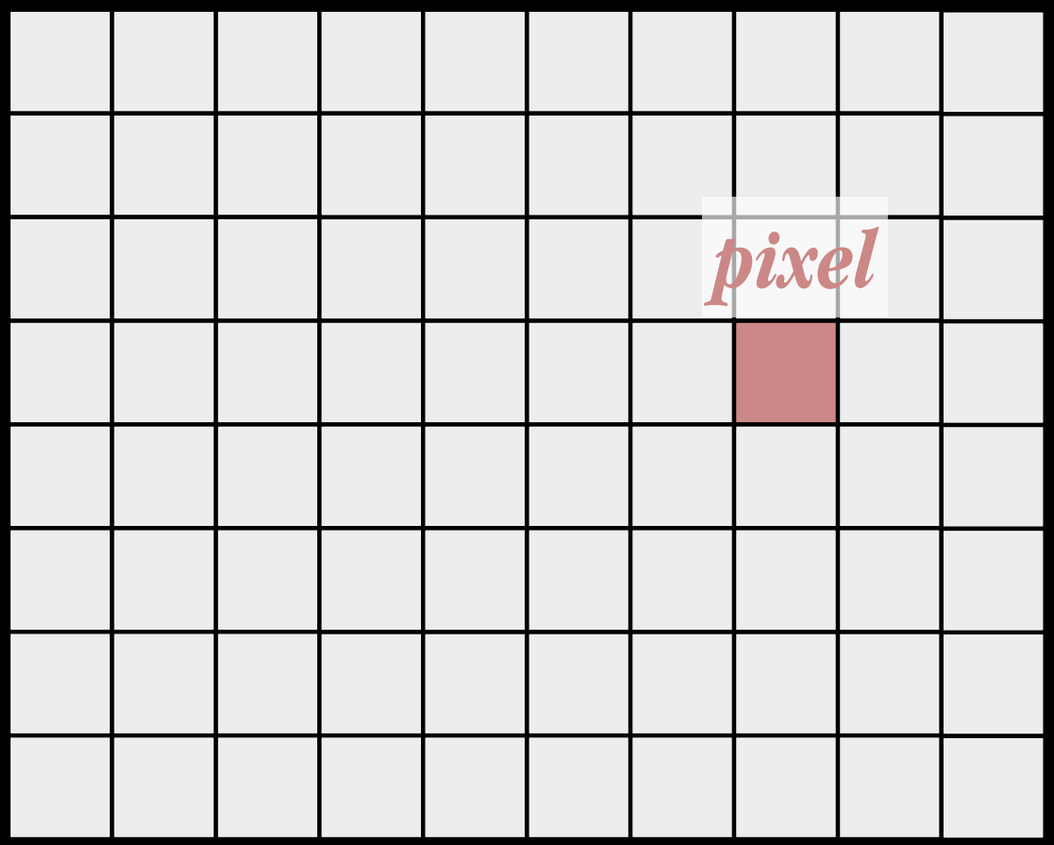
youtube.com/watch?v=ijxwdV_ZWnc

Simulation-Observation Comparison

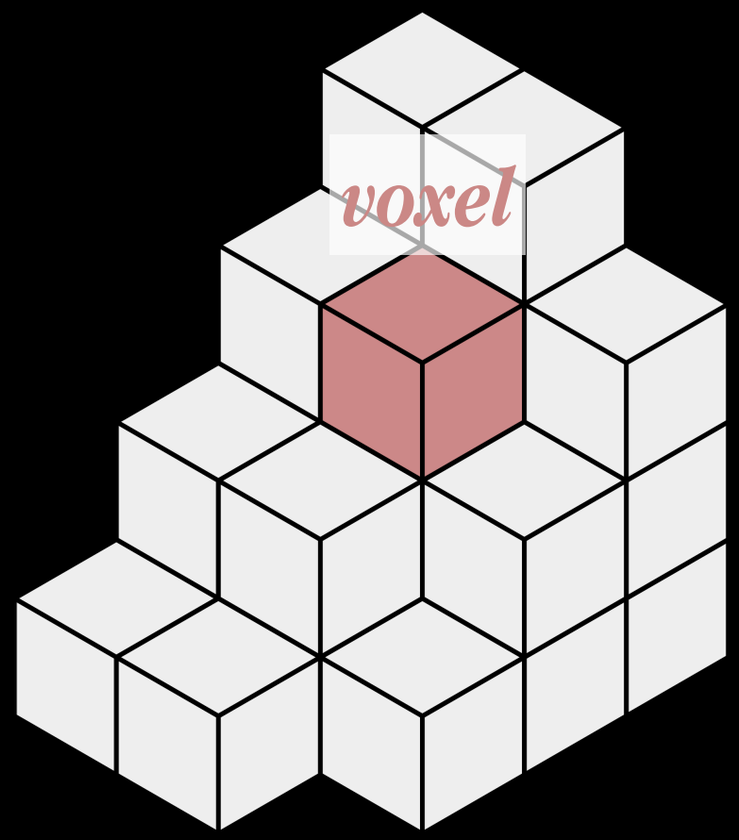
Collisions sim vs. ops https://www.youtube.com/watch?v=C0XNyTp5brM

Simulation Essentials Refresher

2D computational zones are called “pixels” or “grid cells”

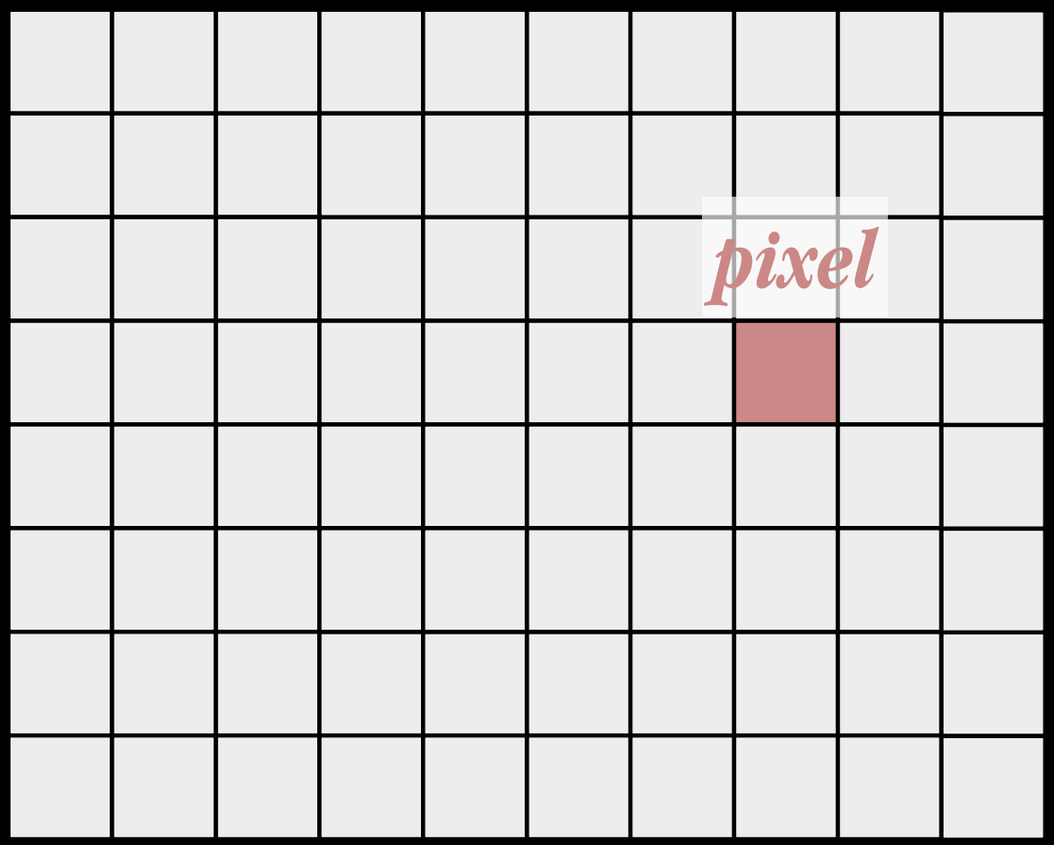


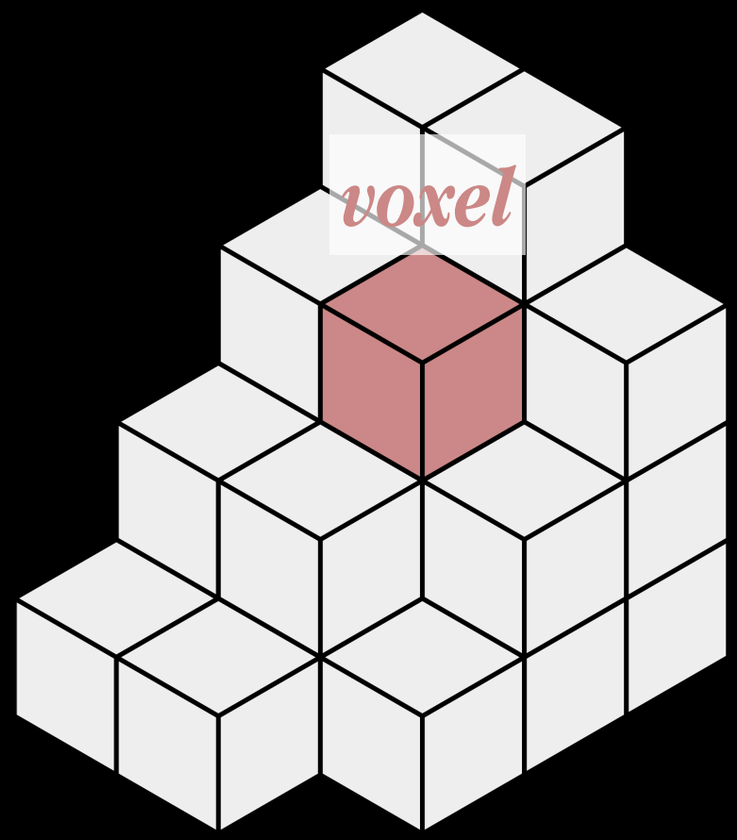
3D computational zones are called “voxels” or “grid cells”



#resolution #simulation_or_model #technology_theoretical_computation_and_math

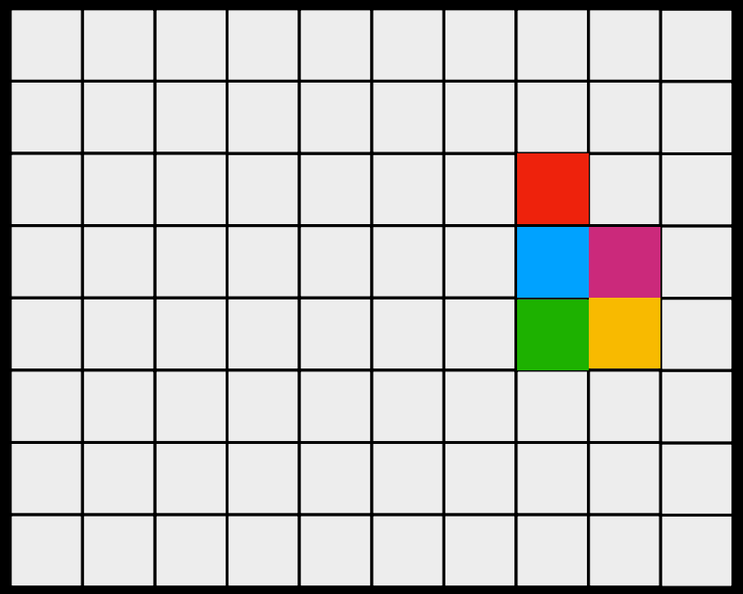
The rules applied in a simulation give an “update” for what happens in each “pixel” or “voxel” depending on what happens in neighboring cells.





The resolution in any simulation cannot be finer, in space, than the size of the smallest grid cell, or in time than the smallest time step.

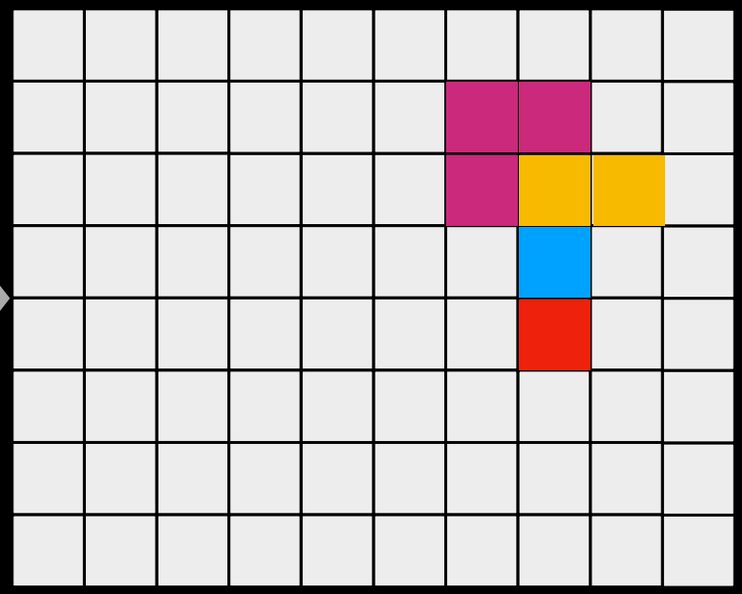
“Time Step n”



System is in some “state” shown by the arrangement of colors in the pixels

PREDICTIVE SYSTEM

“Time Step n+1”



System is in new “state” shown by the new arrangement of colors in the pixels

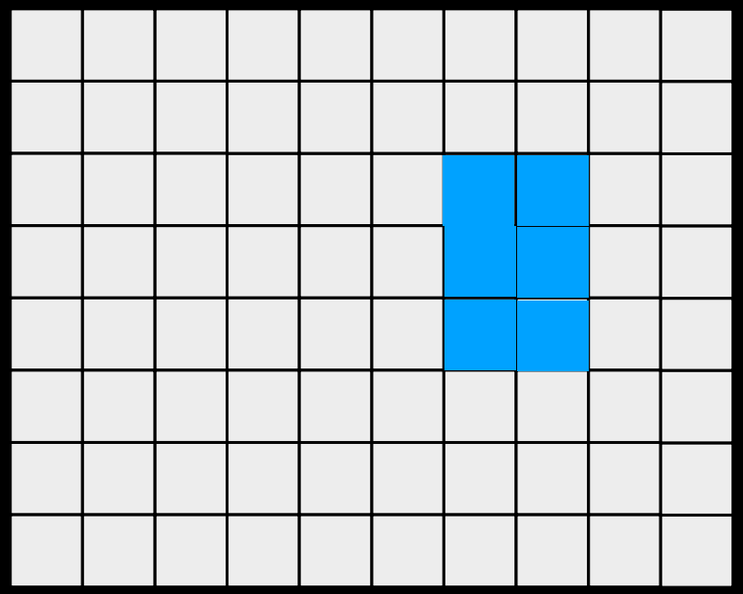
The resolution in any simulation cannot be finer, in space, than the size of the smallest grid cell, or in time than the smallest time step.

INPUTS

PREDICTIVE SYSTEM

OUTPUTS

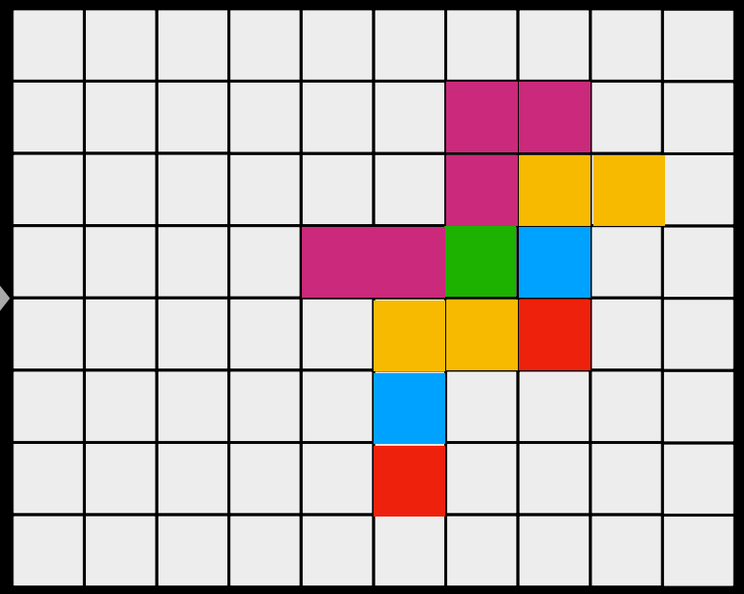
Initial Conditions



This starting state is determined by **INPUTS** to the predictive system.

after total # of steps…

Final Conditions

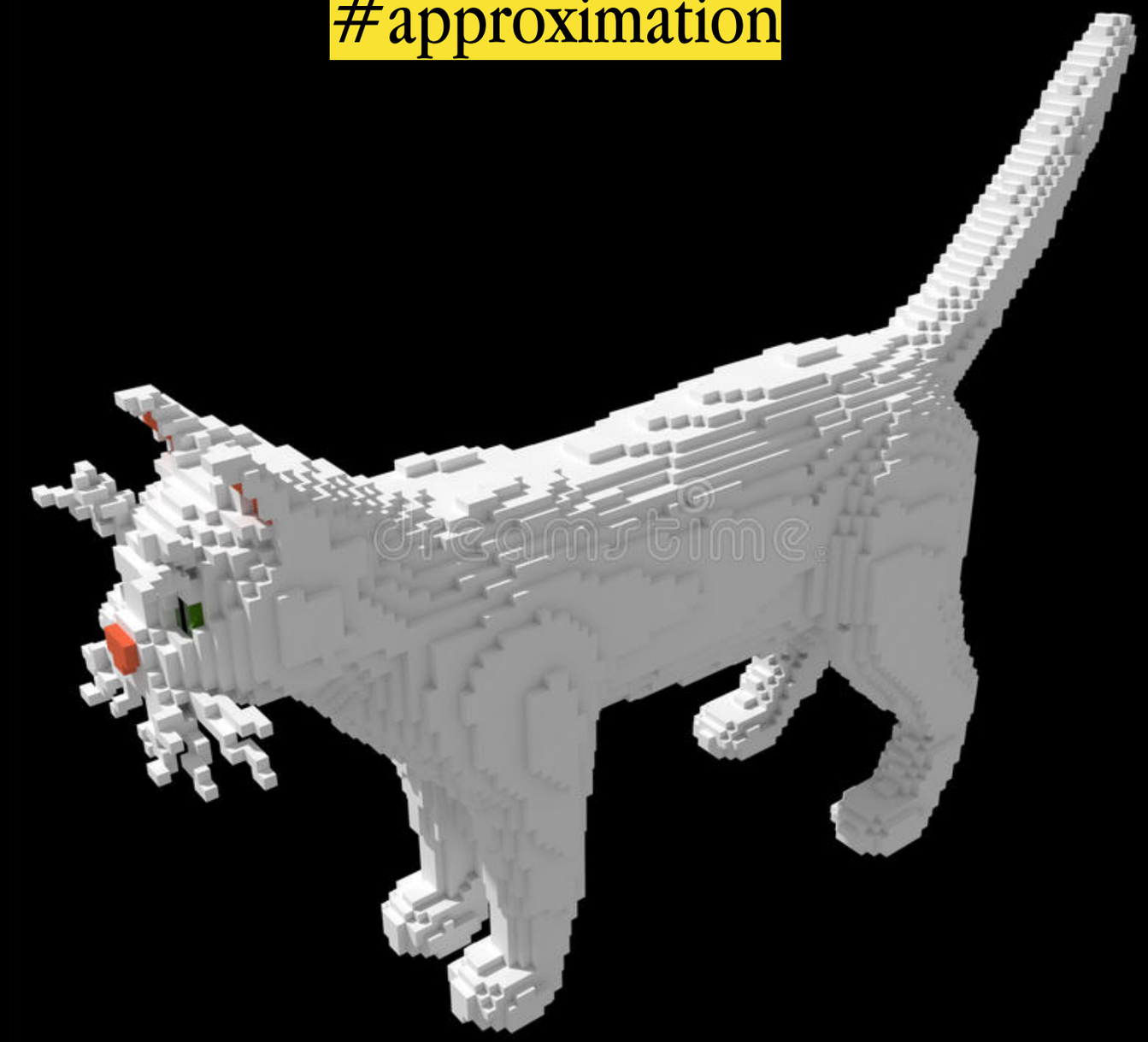


At the last time step, the state of the simulation is the **OUTPUT**.

The resolution in any simulation cannot be finer, in space, than the size of the smallest grid cell, or in time than the smallest time step.

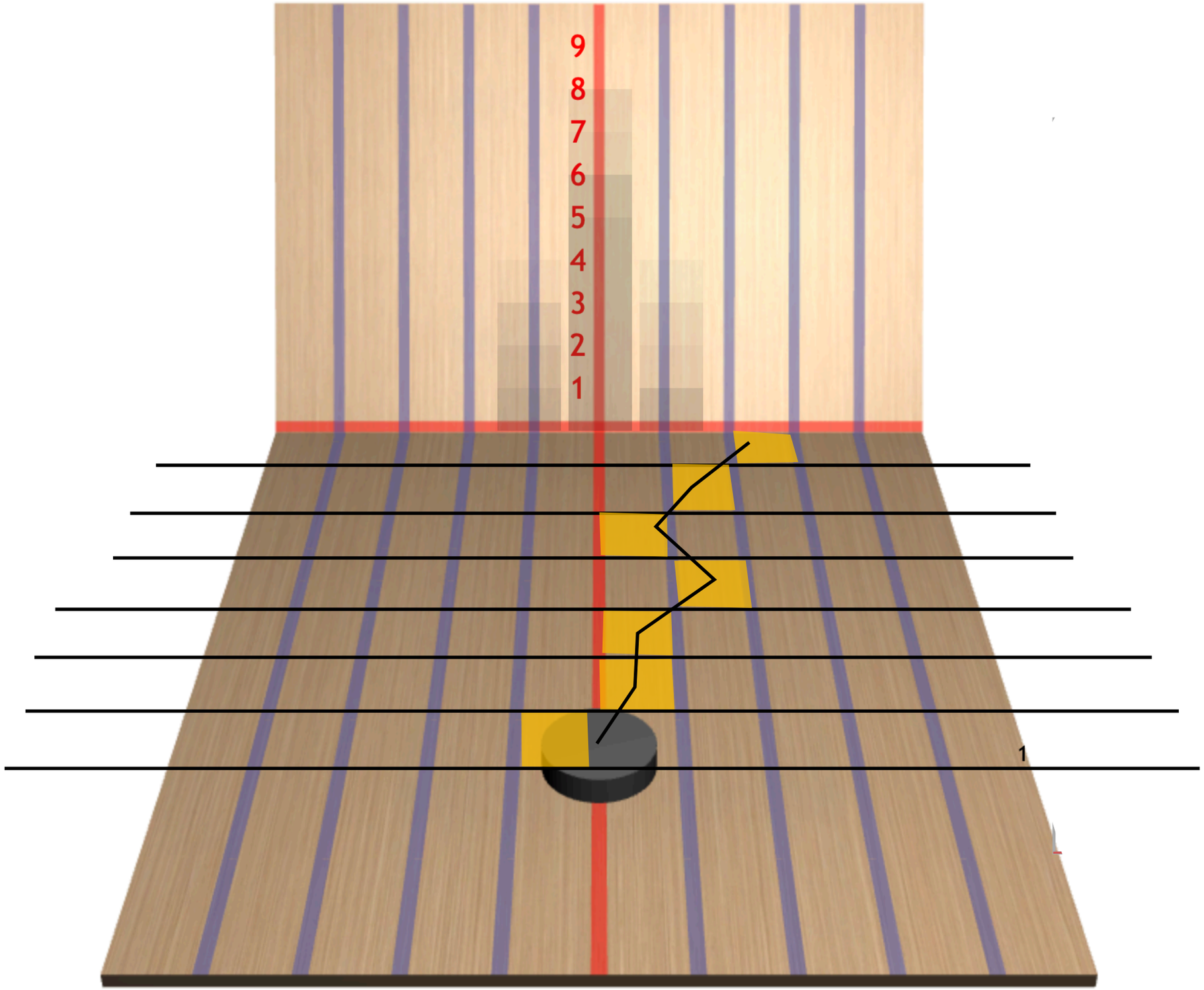
#resolution (and #approximation)

#approximation



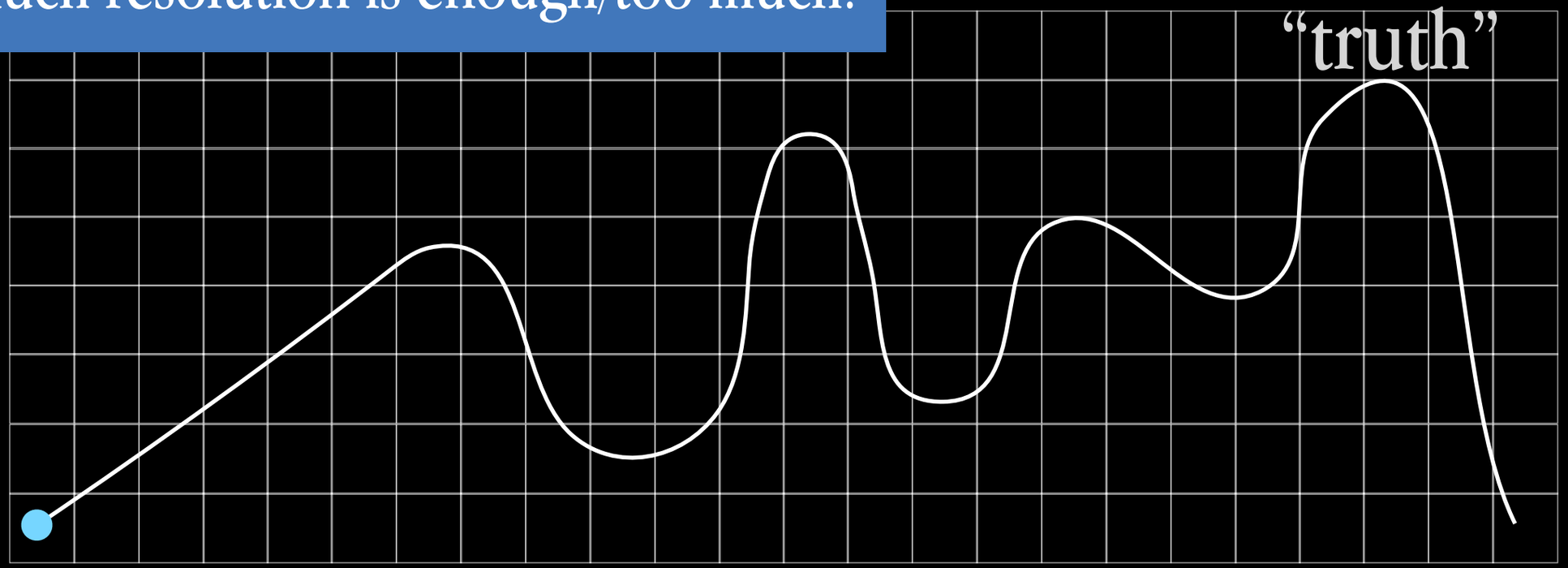
https://www.dreamstime.com/stock-illustration-d-voxel-cat-image-white-made-blocks-voxels-side-view-isolated-black-background-image76450879

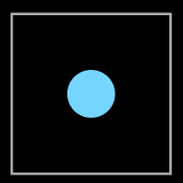
The path of the puck looks jerky when you play because the **temporal** and/or **spatial** #resolution of the situation is low (not very good).



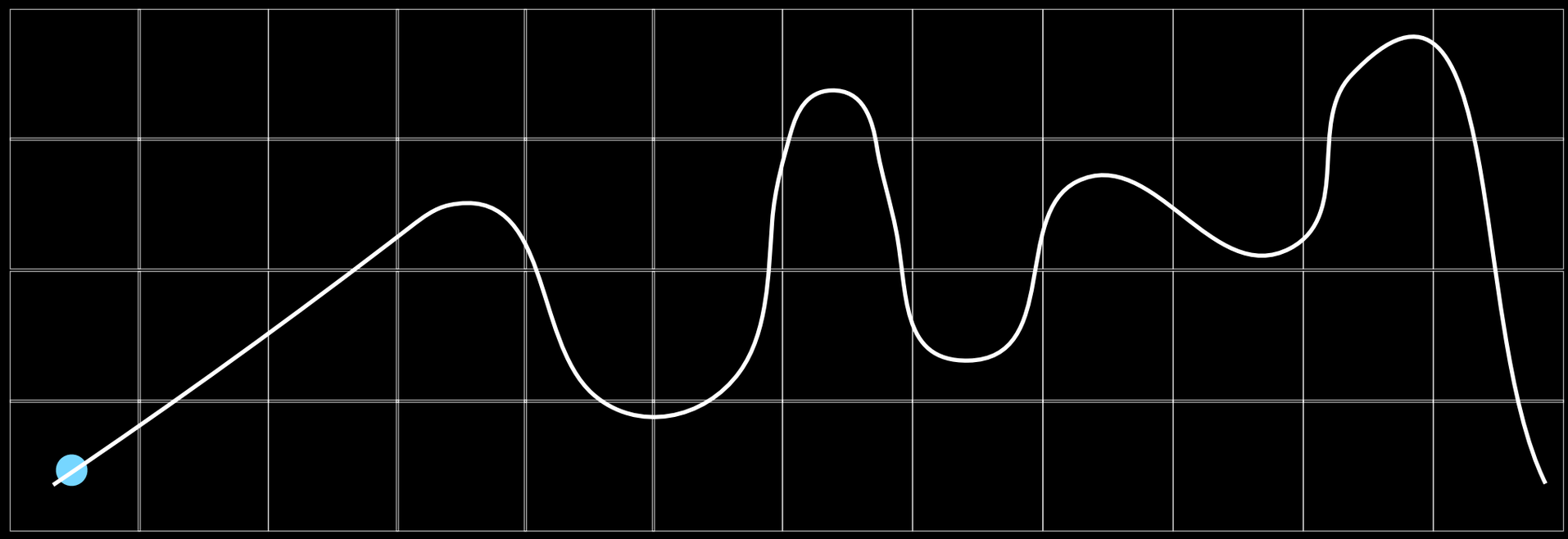
How much resolution is enough/too much?

#resolution #approximation

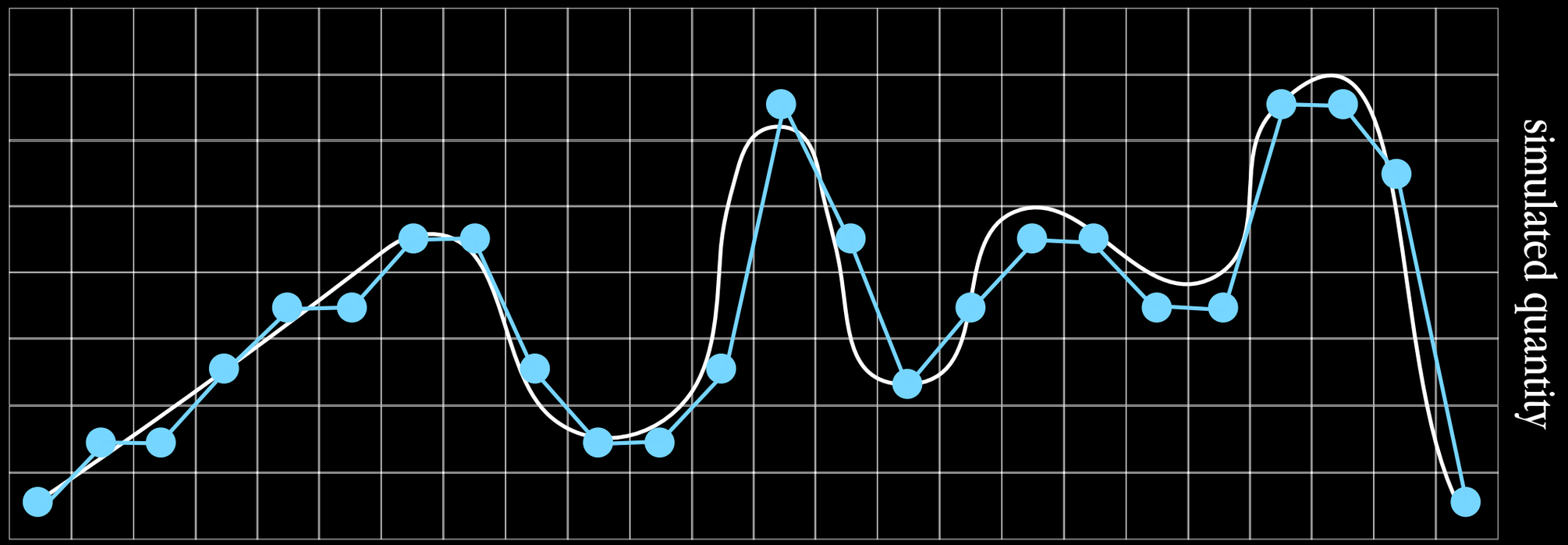


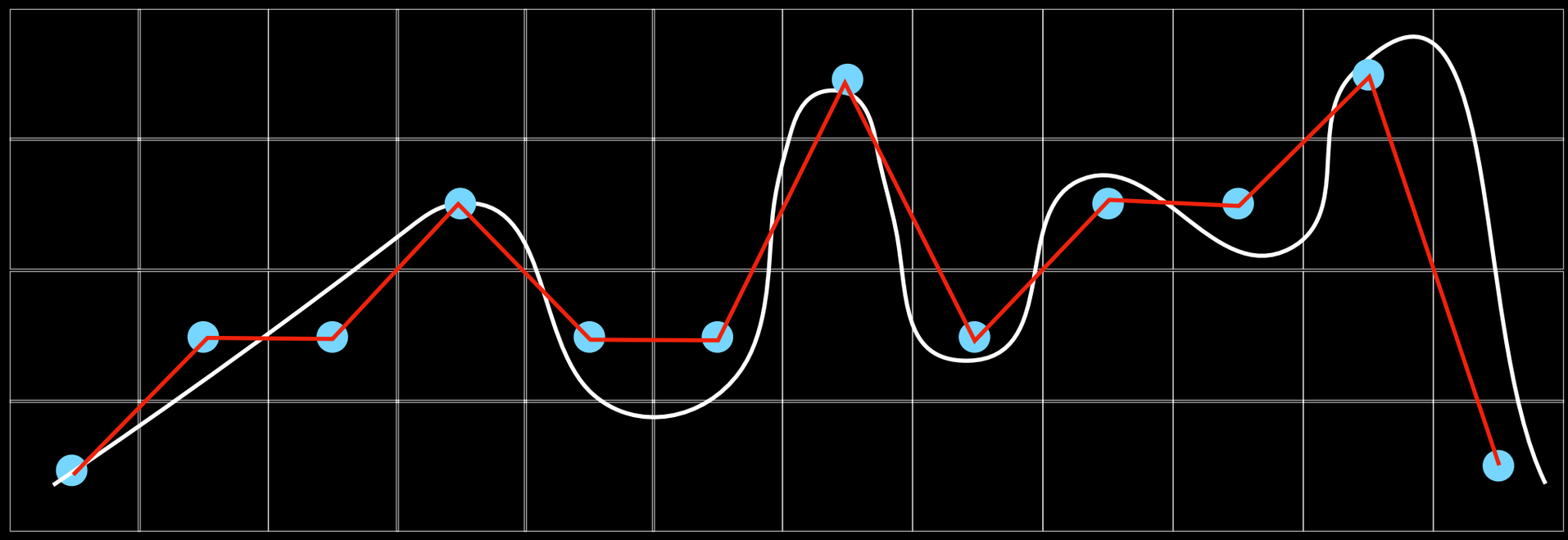


at each time step, the blue dot moves to the closest the exact CENTER of the nearest "grid" cell

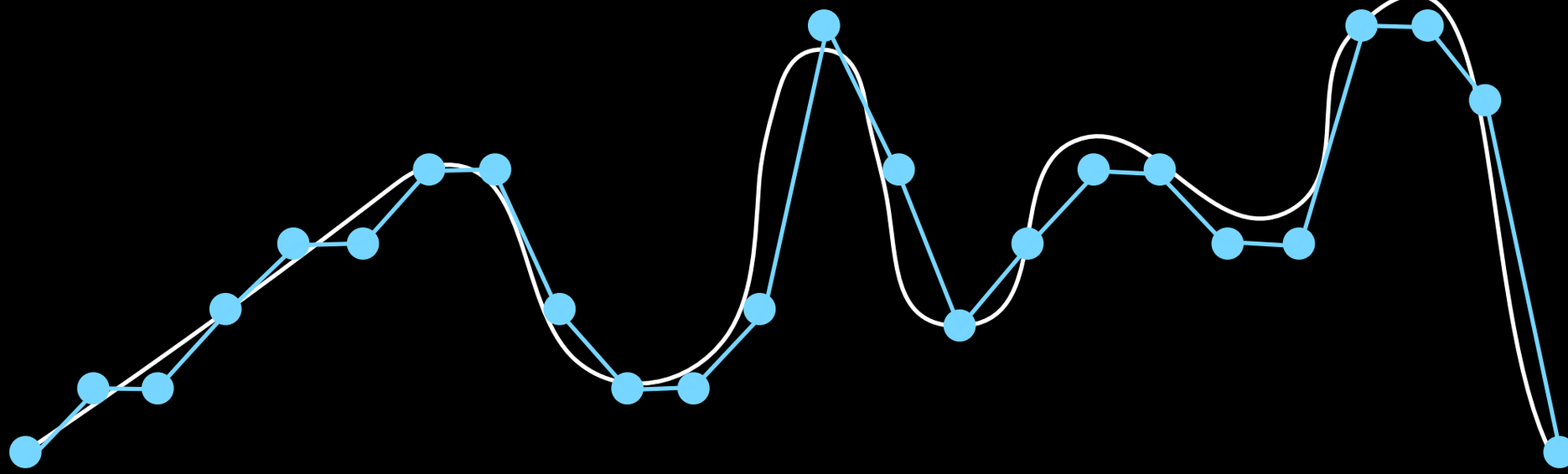


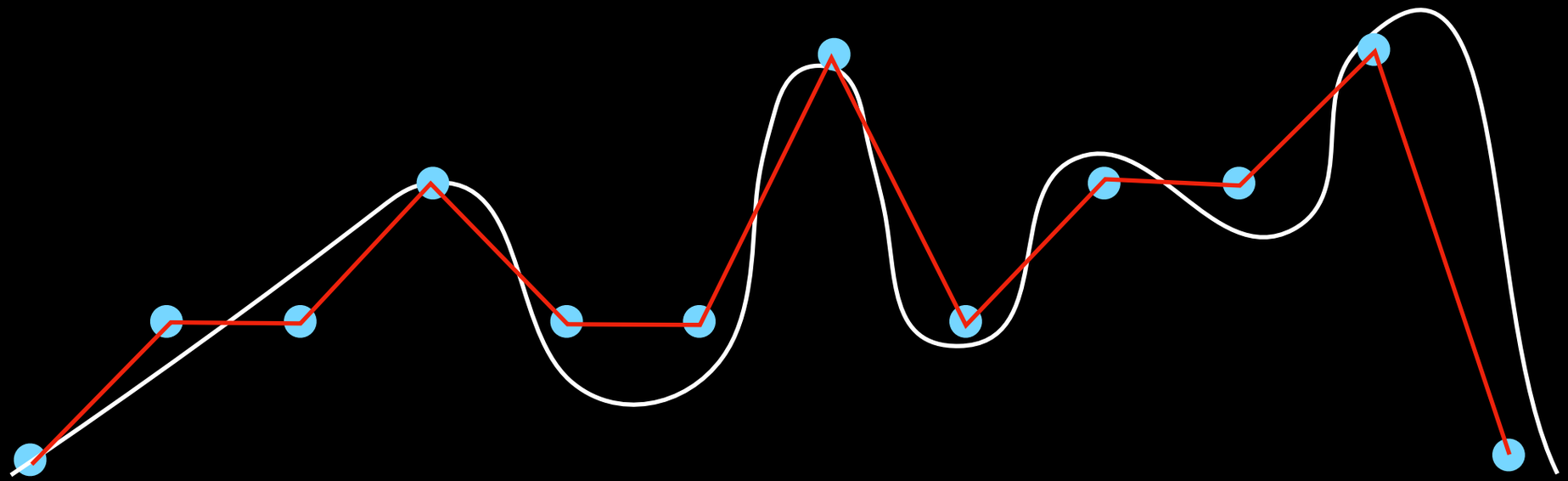
#resolution #approximation

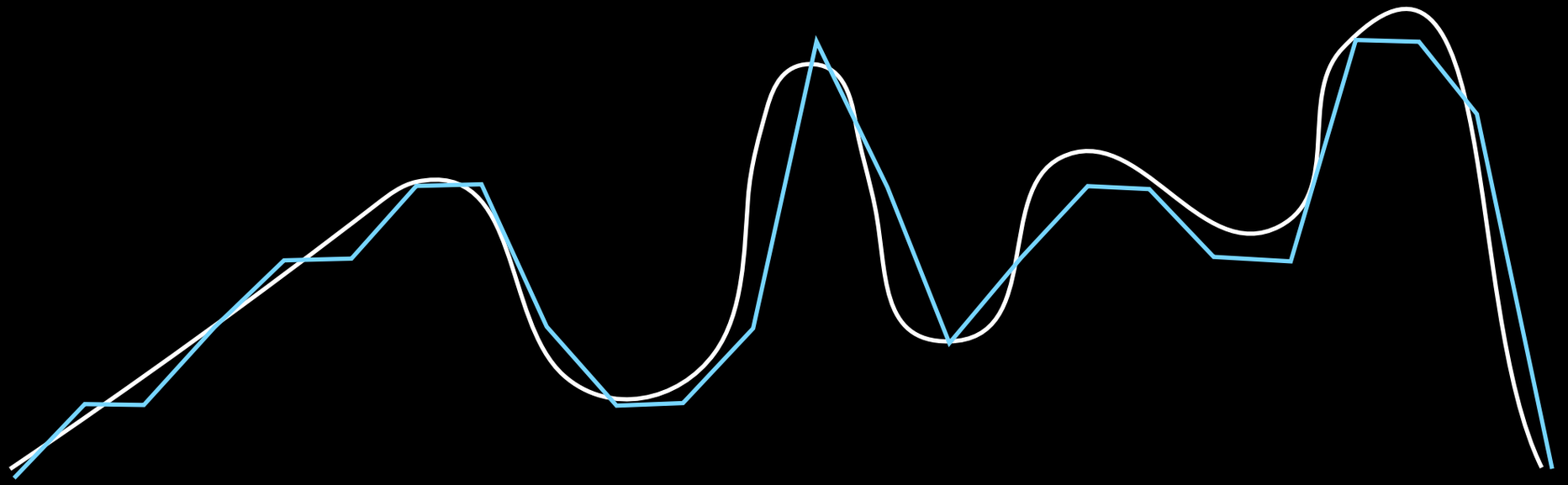


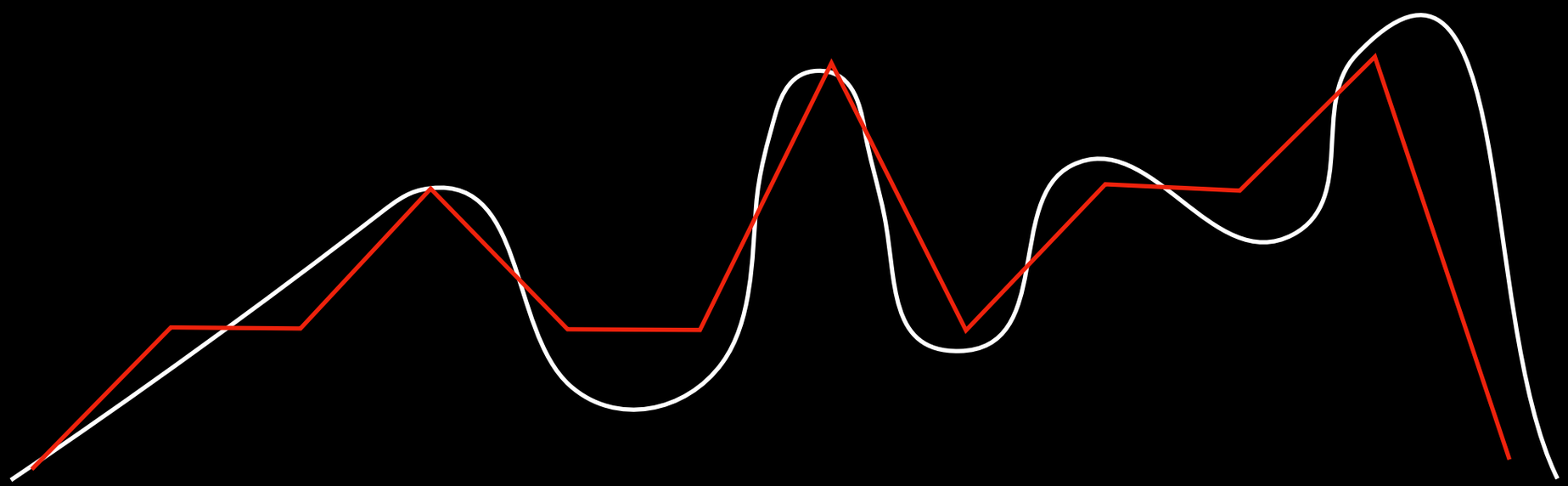


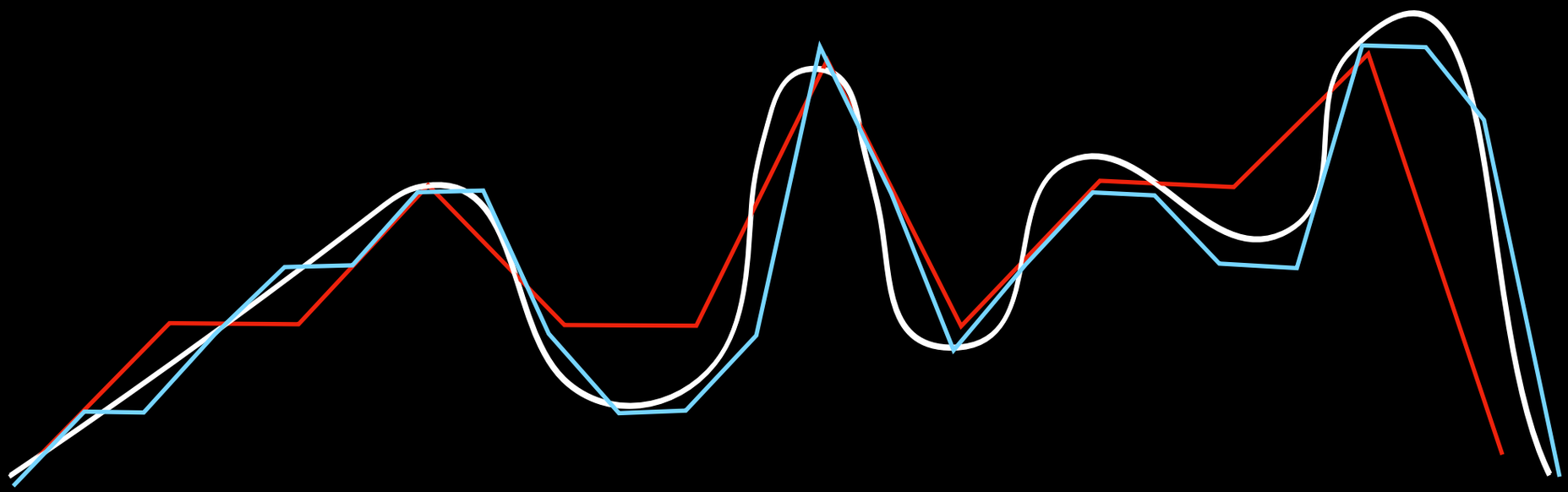
#resolution #approximation



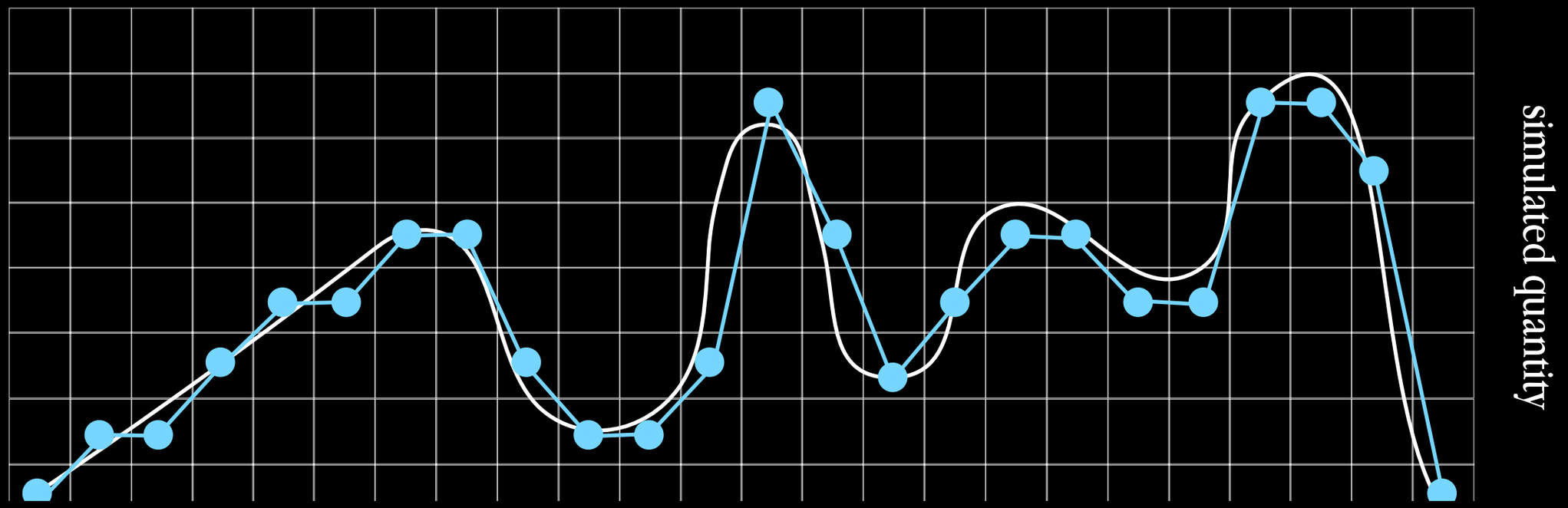




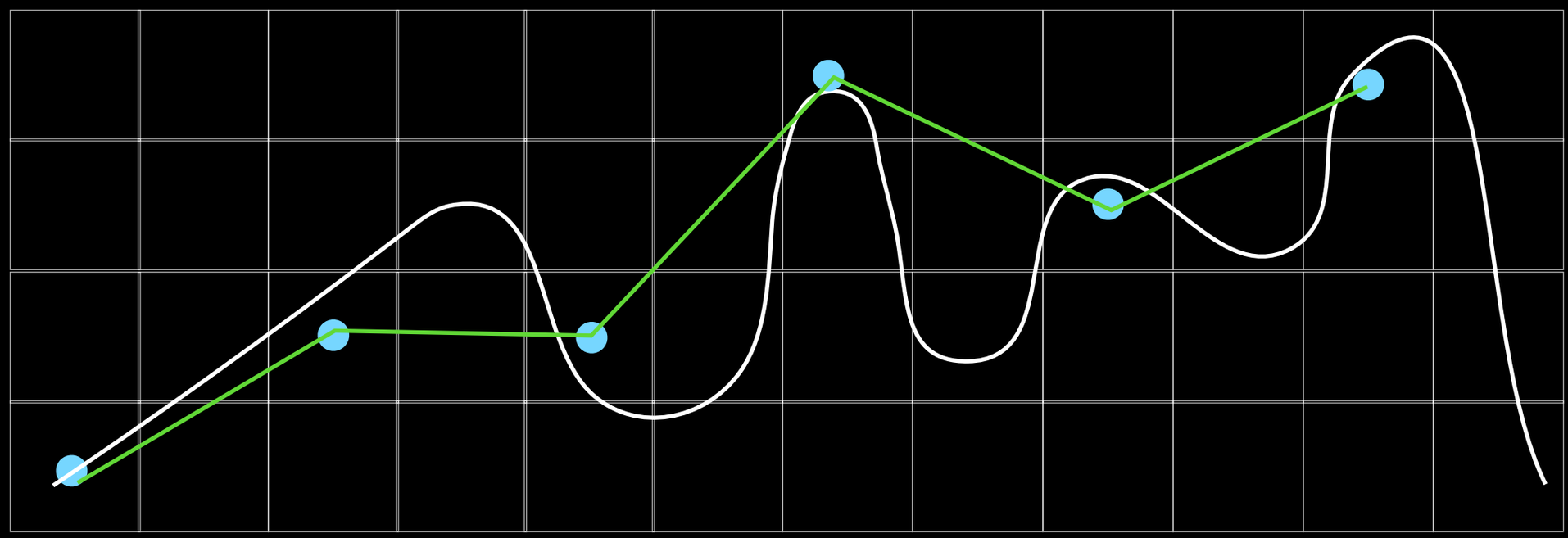




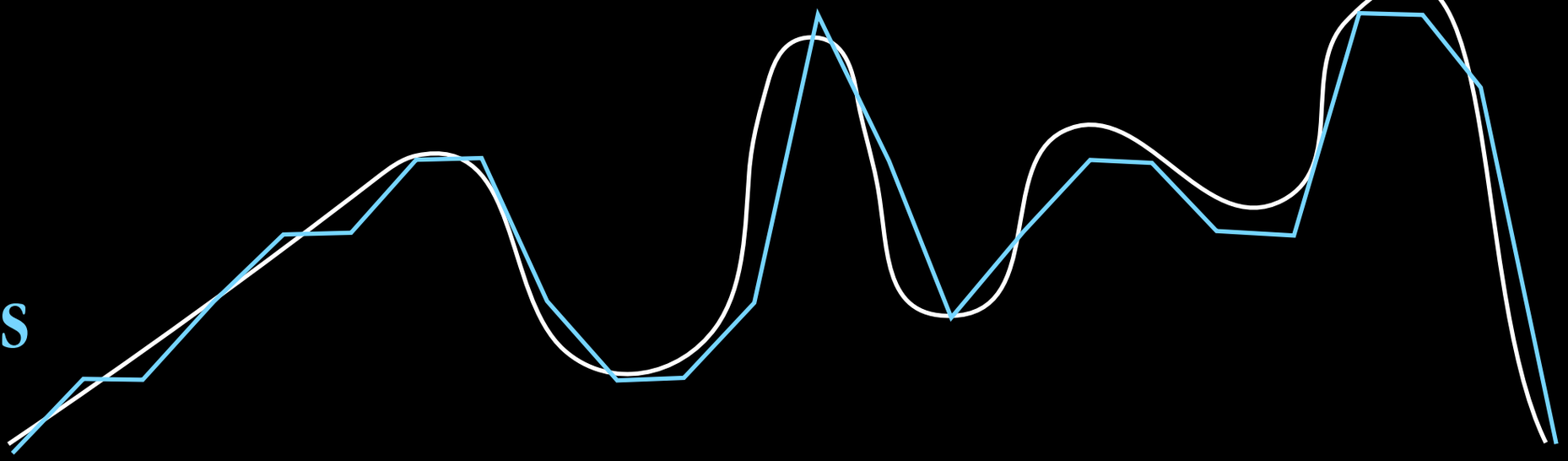
What about even lower resolution?



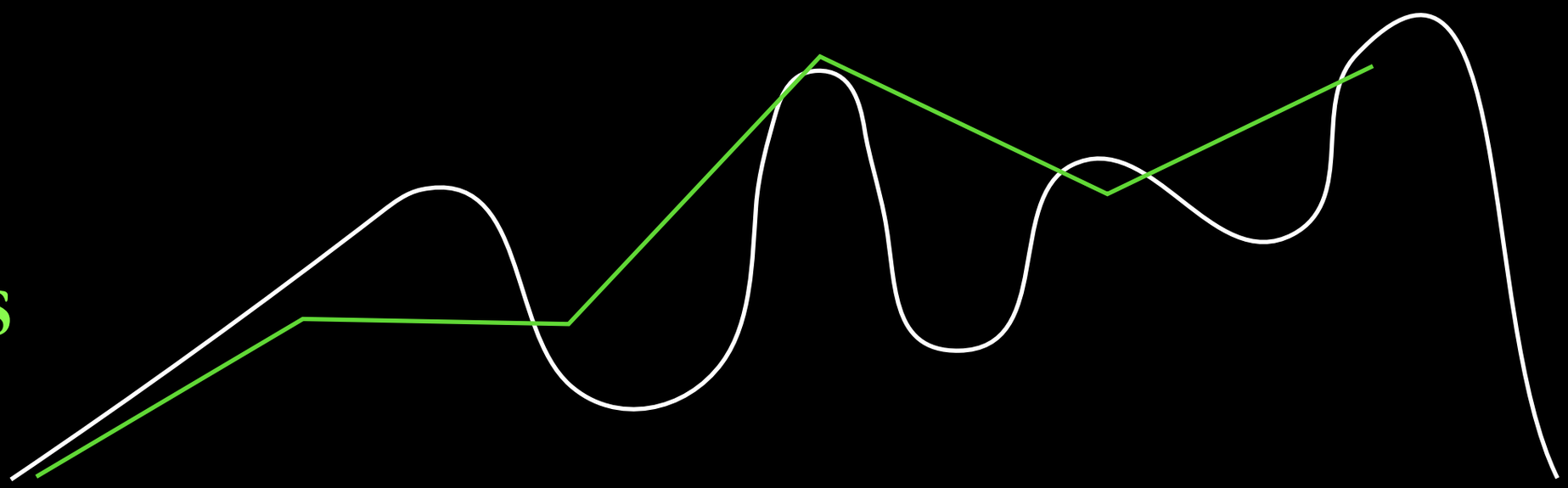
What about even lower resolution?

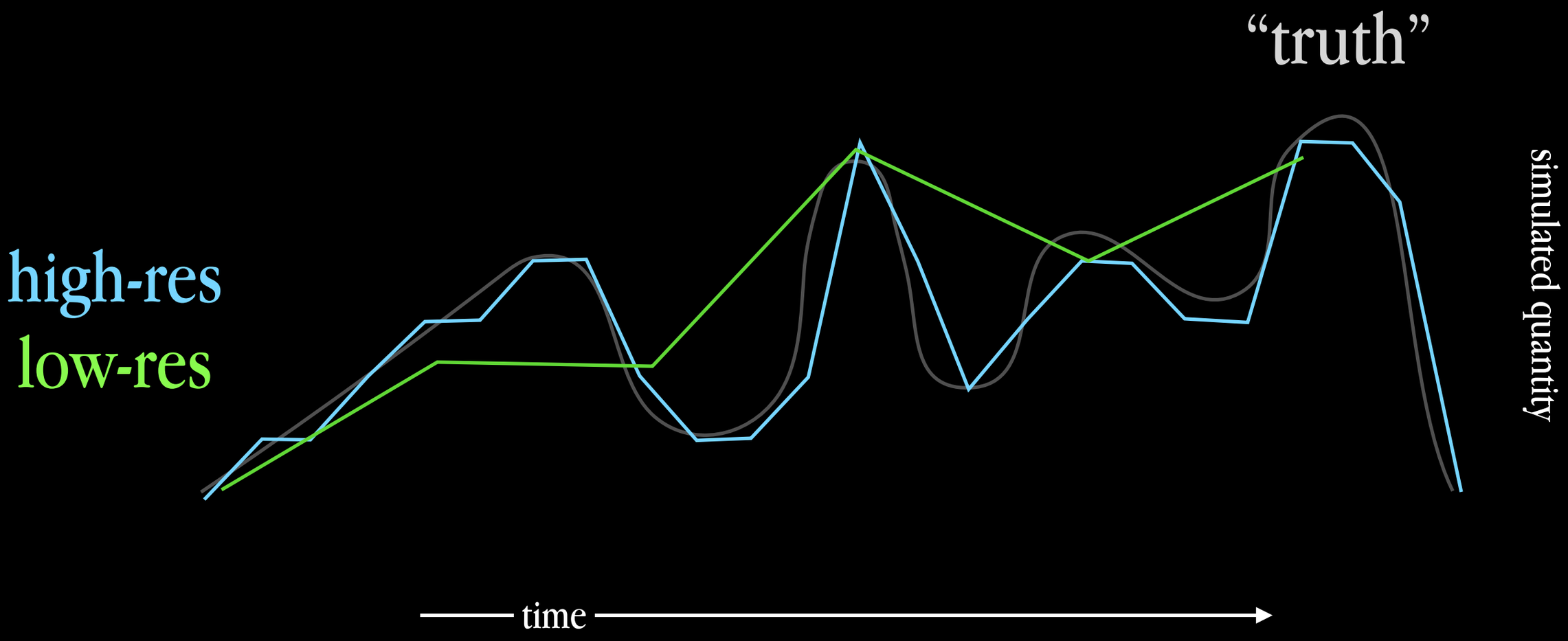


high-res

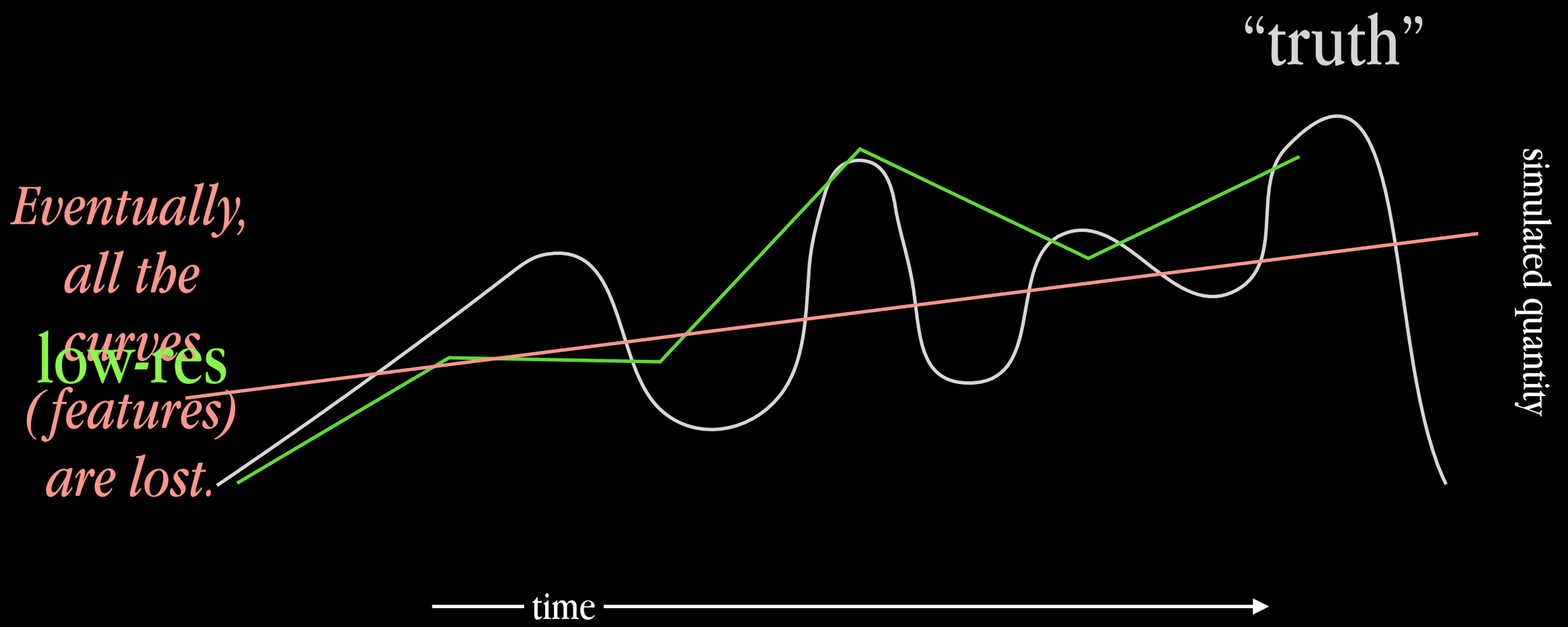


low-res




“truth”
high-res
low-res
simulated quantity
time

#resolution #approximation



Very clever modern simulation "meshes" *move* and *adjust* with what's happening in the simulation. #resolution *is thus variable.* (e.g. Arepo "moving mesh" code, using Voronoi tessellation)

FYI—same "Vornoi" idea gives the curved line on the "original" John Snow map.

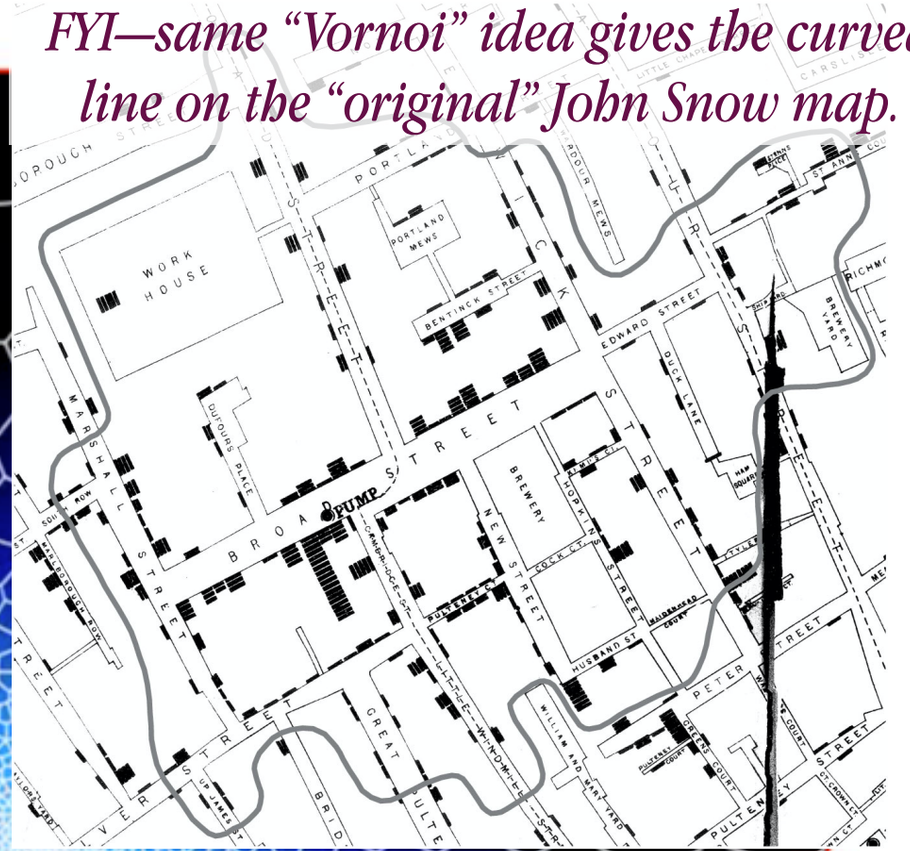
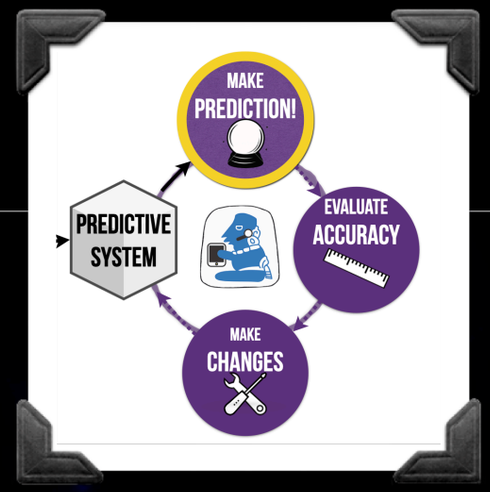


Image credit: Volker Springel, wwwmpa.mpa-garching.mpg.de/~volker/arepo/

How much physics is enough/too much?



z=10.0

adiabatic

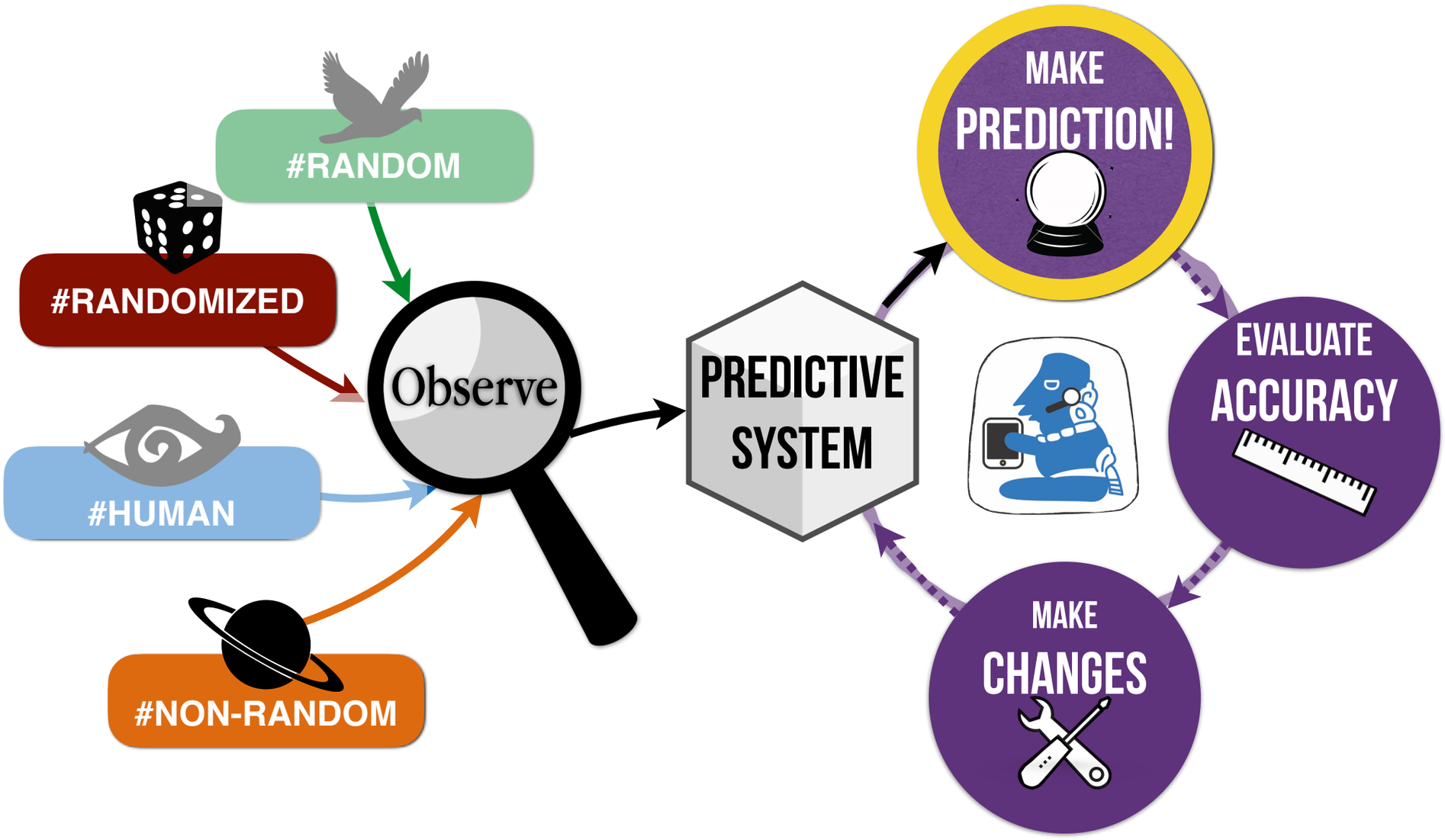
cooling+SF+AGN

ILLUSTRIS

Time evolution of a 10Mpc (comoving) over-dense region within Illustris. While the right side shows a full-physics simulation that includes gas cooling, as well as stellar and black hole formation and feedback, the left side shows a simple simulation of the same region, which includes only gravity and hydrodynamics.

SPACE FUTURES

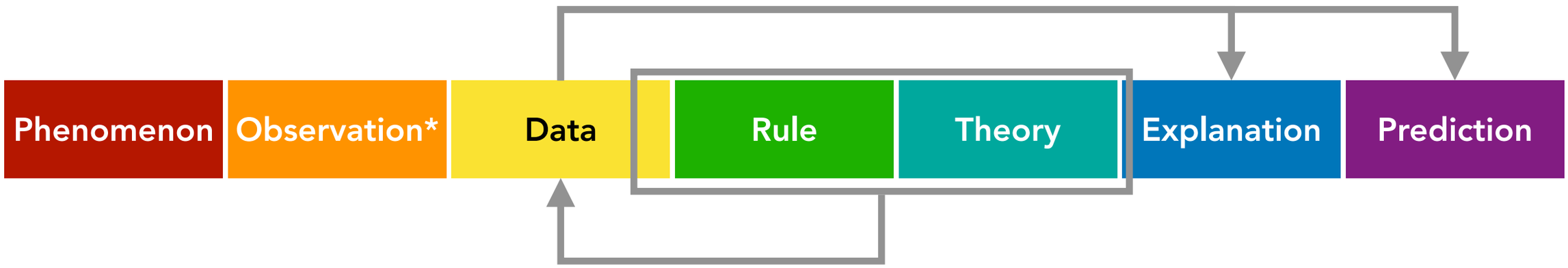
& the PredictionX Framework



https://openclipart.org/

SPACE FUTURES

& The Padua Rainbow



Some “**Data**” are used to provide “initial conditions,”

then, as **Rules** and **Theories** are applied,

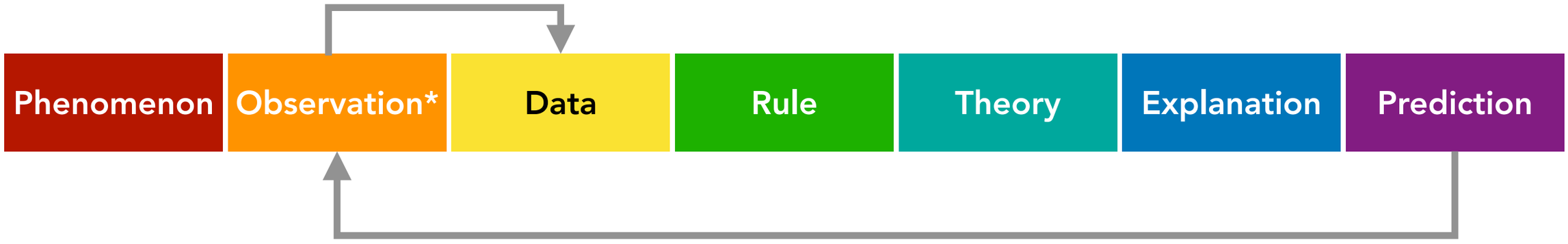
more “**Data**” are generated as simulation output,

and used to offer **Explanations** and/or **Predictions**.

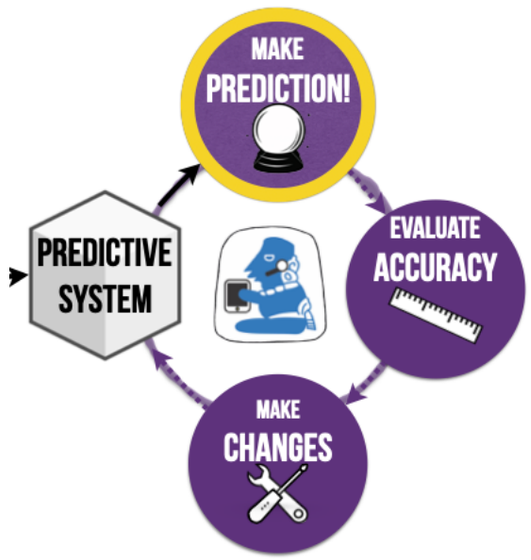
or, Experiment

SPACE FUTURES

& Synthetic Observations



Synthetic "Observations" are created by simulating particular observing techniques, generating synthetic "Data"



Which, after statistical comparison with real Data, facilitate improvement, as in the framework.

or, Experiment

SPACE FUTURES with 2 of your expert astrophysicist TFs

Padua Rainbow for the theory of galaxy evolution

Phenomenon	Observation*	Data	Rule	Theory	Explanation	Prediction

. Images in different wavelength
. Spectra

Local galaxies

Simulation is used to apply:
- Known physics theory (i.e. gravity, hydrodynamics, etc)
- Empirical correlation
- Analytical theory

(see Mila's presentation)

Pipit Triani

Dr. Pipit Triani's Slides

The **same principles**, applied to not just stars but also gas and dark matter, **allow us to understand the evolution of the entire Universe** over billions of years

Mila Chadayammuri

Dr. Mila Chadayammuri's Slides

Human behavior, then aliens

SPACE FUTURES discussions

The Drake Equation

Federico Slepoi, Behavioral Economist

ROMA

Federico Raimondi Slepoi

Roma Capitale
R^2 - Ufficio di Scopo Innovazione per le Politiche Comportamentali

Jill Tarter, SETI expert

INTERACTIVE VIDEO
PREDICTIONX
THE SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE

1. The Search for Extraterrestrial Intelligence

00:26:06

What can we predict about humanity's response to first contact with extraterrestrial civilization? Will we come in peace, will they?

Watch clip | Learn more

#human_response #arrival #first_contact #aliens

00:30:08

Why the Search for Extraterrestrial Intelligence is no longer government-funded.

Watch clip

#fear #government_and_aliens

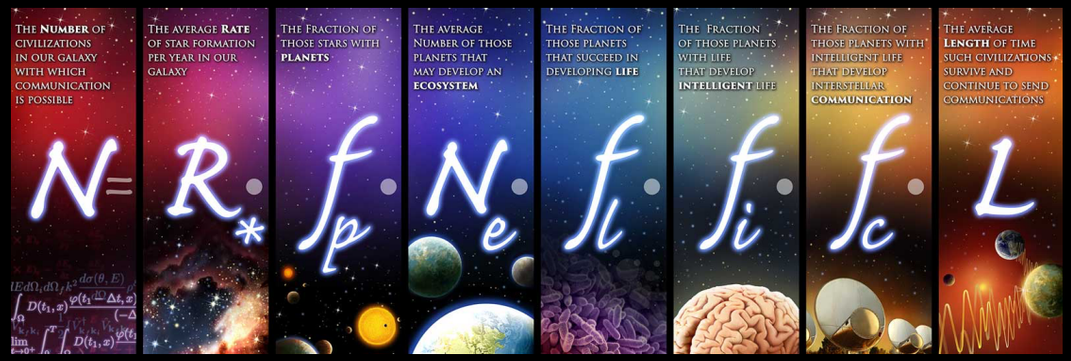
00:34:01

What is the future of manned space flight? Will it be us or robots who explore space?

+ Tarter's question for aliens (as in CONTACT):
How did you make it through this technological adolescence?

The Drake Equation

The Drake Equation



Jodie Foster & Matthew McCounaghey in the movie CONTACT, copyright Warner Brothers 1997 (reproduced for educational use only) Disclaimer: Jill Tarter does not like mis-use of the Drake equation, which includes this scene.

The Drake Equation

Are We Alone in the Universe?

Calculate the Chance of Intelligent Alien Life with the Drake Equation

In 1961, Astronomer Frank Drake came up with an equation to estimate how many detectable extraterrestrial civilizations might exist in our galaxy. Each variable is a crucial factor for the development of alien life.

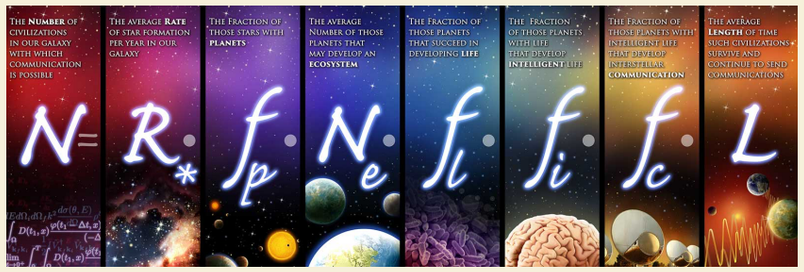
today's optimistic | lowest possible | original drake values | today's skeptical

No. of new stars born per year — f_p — **Average no. of habitable planets per solar system** — f_l — **% chance that life develops intelligence** — f_c — n_r

R^*	f_p	n_e	f_l	f_i	f_c	L	n_r
7	90	0.3	10	1	1	10,000,000	3
No. of new stars born per year	% of stars with planets	Average no. of habitable planets per solar system	% chance a habitable planet develops life	% chance that life develops intelligence	% chance life can communicate across space	No. of times civilisation could re-develop	

Calculate

Optional addition allows for the chance of civilization to re-evolve after collapse. An intuitive addition if you consider the billion year lifespan of planets.

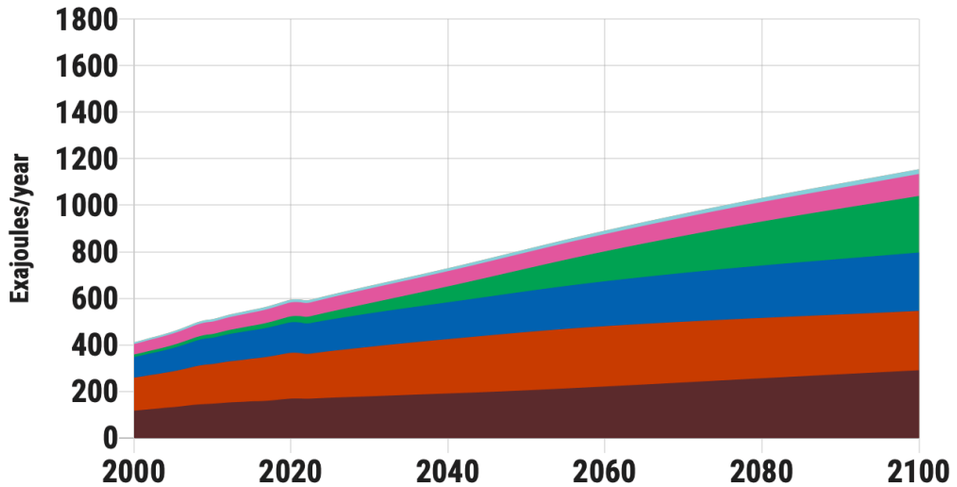


informationisbeautiful.net/visualizations/the-drake-equation/

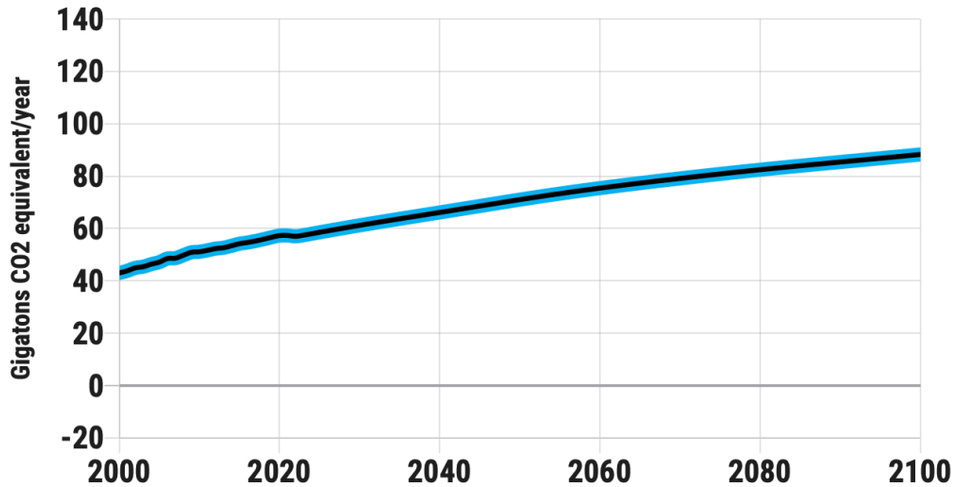
EARTH'S FUTURE: NEXT TIME

EN-ROADS | English | Simulation | Graphs | View | Help | Share Your Scenario

Global Sources of Primary Energy



Greenhouse Gas Net Emissions



+3.6 °C

+6.4 °F

Temperature Increase by 2100

COAL | OIL | GAS | RENEWABLES | BIOENERGY | NUCLEAR | NEW ZERO

BASELINE | CURRENT SCENARIO

Energy Supply

- Coal — status quo
- Renewables — status quo
- Oil — status quo
- Nuclear — status quo
- Natural Gas — status quo
- New Zero-Carbon — status quo
- Bioenergy — status quo
- Carbon Price — status quo

Transport

- Energy Efficiency — status quo
- Electrification — status quo

Buildings and Industry

- Energy Efficiency — status quo
- Electrification — status quo

Growth

- Population — status quo
- Economic Growth — status quo

Land and Industry Emissions

- Deforestation — status quo
- Methane & Other Gases — status quo

Carbon Removal

- Afforestation — status quo
- Technological — status quo

CLIMATE INTERACTIVE

MIT MANAGEMENT Sustainability Initiative

Register Your En-ROADS Event

https://en-roads.climateinteractive.org/scenario.html

SPACE FUTURES discussions

Space Futures (proposed Questions)