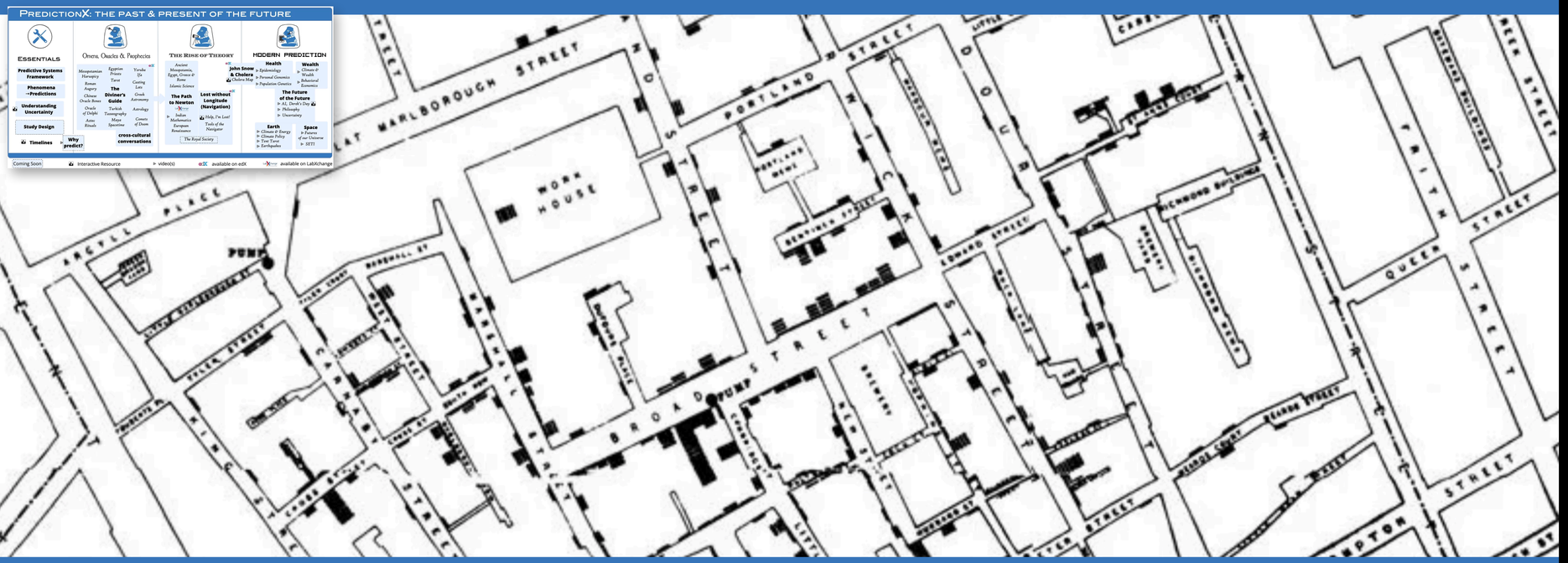
PART 1: THE PREDICTION PROJECT

Alyssa Goodman,
for London Vallery, with many thanks to Annie Valva,
Curtis Wong, Howard Cutler, Immaculata De Vivo,
Drew Lichtenstein, Jais Brohinsky, and *MANY* others

predictionx.org

The Prediction Project

The Past and Present of the Future



Prediction Essentials

Take a look at the essential elements of the course, including the framework for predictive systems.

→

Omens & Oracles

Gain insight into prediction as a human venture by studying the most ancient forms of prediction in Omens and Oracles.

→

Rise of Theory

Learn how humanity moved from mystical divination practices to the use of scientific theories to explain natural phenomena.

→

Modern Prediction

Discover the cutting edge predictive methods and modeling from preeminent experts across many fields.

→

The Prediction Project

PredictionX: The Past & Present of the Future

Essentials

- **Predictive Systems Framework**
- **Phenomena →Predictions**
- **Understanding Uncertainty**
- **Study Design**
- **Timelines**
- ▶ **Why predict?**

Omens, Oracles & Prophecies

edX

- *Mesopotamian Haruspicy*
- *Egyptian Priests*
- *Yoruba Ifa*
- *Tarot*
- *Roman Augury*
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- *Aztec Rituals*
- *Maya Spacetime*
- *Comets of Doom*

cross-cultural conversations

The Rise of Theory

- *Ancient Mesopotamia, Egypt, Greece & Rome*
- *Islamic Science*
- **The Path to Newton** (LabXchange)
  - ▶ *Indian Mathematics*
  - *European Renaissance*
- **Lost without Longitude (Navigation)** (edX)
  - *Help, I'm Lost!*
  - *Tools of the Navigator*
- *The Royal Society*

edX **John Snow & Cholera**
- *Cholera Map*

Modern Prediction

Health
- ▶ *Epidemiology*
- ▶ *Personal Genomics*
- ▶ *Population Genetics*

Wealth
- ▶ *Climate & Wealth*
- ▶ *Behavioral Economics*

The Future of the Future
- ▶ *AI, Derek's Day*
- ▶ *Philosophy*
- ▶ *Uncertainty*

Earth
- ▶ *Climate & Energy*
- ▶ *Climate Policy*
- ▶ *Tent Tarot*
- ▶ *Earthquakes*

Space
- ▶ *Futures of our Universe*
- ▶ *SETI*

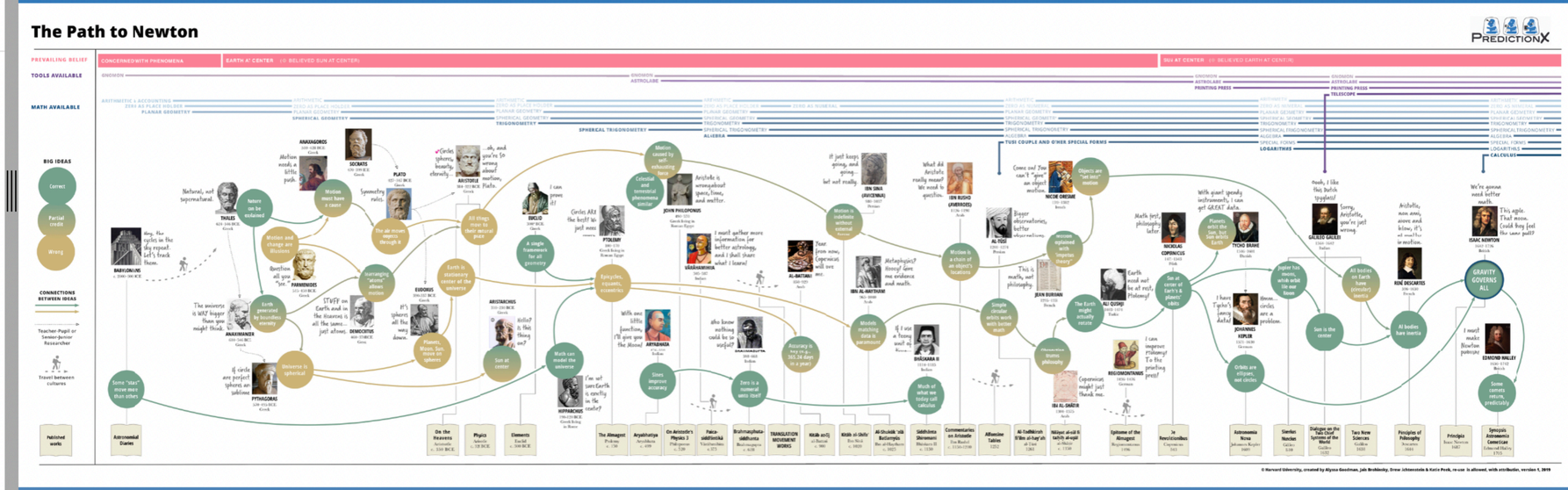
Coming Soon | Interactive Resource | ▶ video(s) | edX available on edX | LabXchange available on LabXchange

natural phenomena.

The Path to Newton

PREAMBLE:

Isaac Newton's theory of gravity was truly revolutionary. For the first time in history, all motion -- from celestial bodies in Space to objects on Earth -- could be mathematically described and predicted. Newton's theory necessitated new mathematics, Calculus, as well as a trove of empirical observations from which to derive and against which to test the math. The observations required instruments, the instruments required inventors, and the inventors required ideas, models, and conceptual systems that tried to make sense of the world and its physical phenomena. Over



The Prediction Project

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Essentials

Phenomenon

Prediction

Phenomena →Predictions

Understanding Uncertainty

Study Design

Timelines

Why predict?

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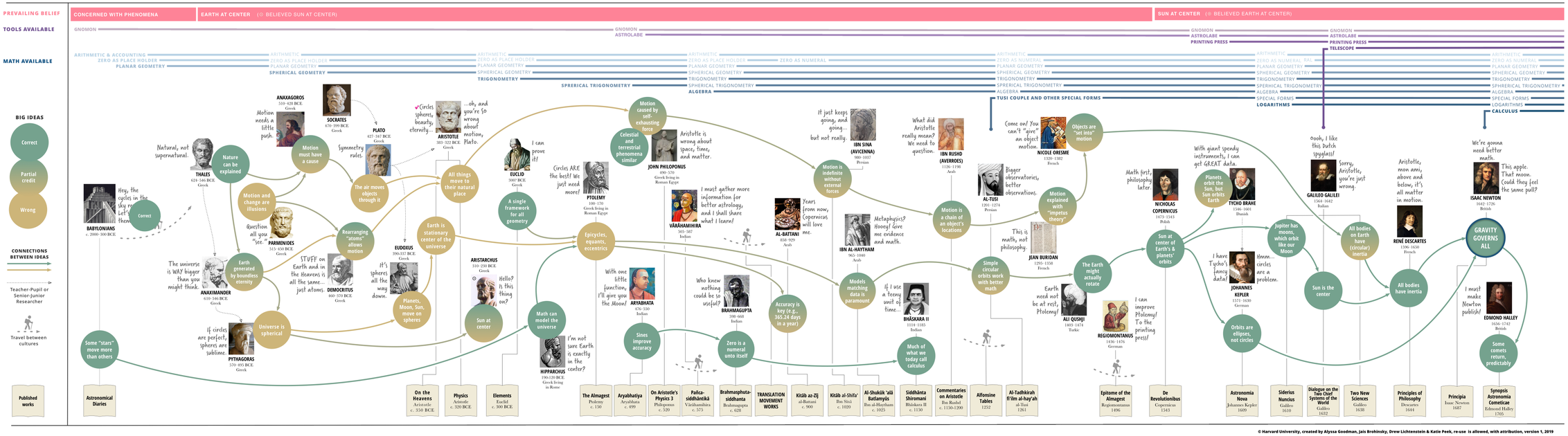
The Path to Newton



(How) The Path to Newton→ The “Padua” Rainbow

Phenomenon	Observation*	Data	Rule	Theory	Explanation	Prediction

or, Experiment

The “Padua” Rainbow

Phenomenon	Observation*	Data	Rule	Theory	Explanation	Prediction

Mendel *1865*

Phenomenon | Observation | Data | Rule | Prediction

Darwin *1859*

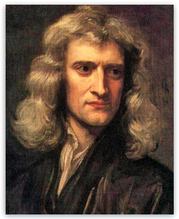
Phenomenon | Observation | Data | Theory | Explanation | Prediction

NO FULLY PREDICTIVE GENERAL THEORY

FULLY PREDICTIVE GENERAL THOERY

Kepler *1609*

Phenomenon | Observation | Data | Rule | Prediction



Newton *1687*

Phenomenon | Observation | Data | Rule | Theory | Explanation | Prediction

The FUTURE of the Future(?)

20th century

21st century?

The Prediction Project

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natural phenomena.

The Prediction Project

The Past and Present of the Future

Search...

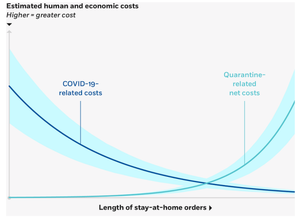
HOME ABOUT MATERIALS COURSES TALKS WRITINGS PRESS FORUM

Writings

This section highlights writings by Professor Goodman on contemporary topics related to uncertainty and prediction. While these pieces are not official Prediction Project material, they contain major conceptual ideas from the Prediction Project's courses applied to major real life questions. These articles reflect Professor Goodman's personal views, not official Harvard policy.

Data Driven Dilemmas Posed by COVID-19

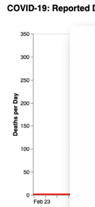
In this essay, Alyssa discusses the **complex tradeoffs** involved with decision making in an age of pandemic. Scientists face ethical dilemmas when choosing to view this crisis in a rational or emotional way.



Read More

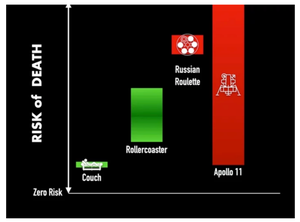
Uncertainty about Uncertainty

This commentary piece examines predictions of uncertainty in IHME COVID-19 models. She sheds light on the tendency of these important models to **underestimate** uncertainty in deaths per day estimates.

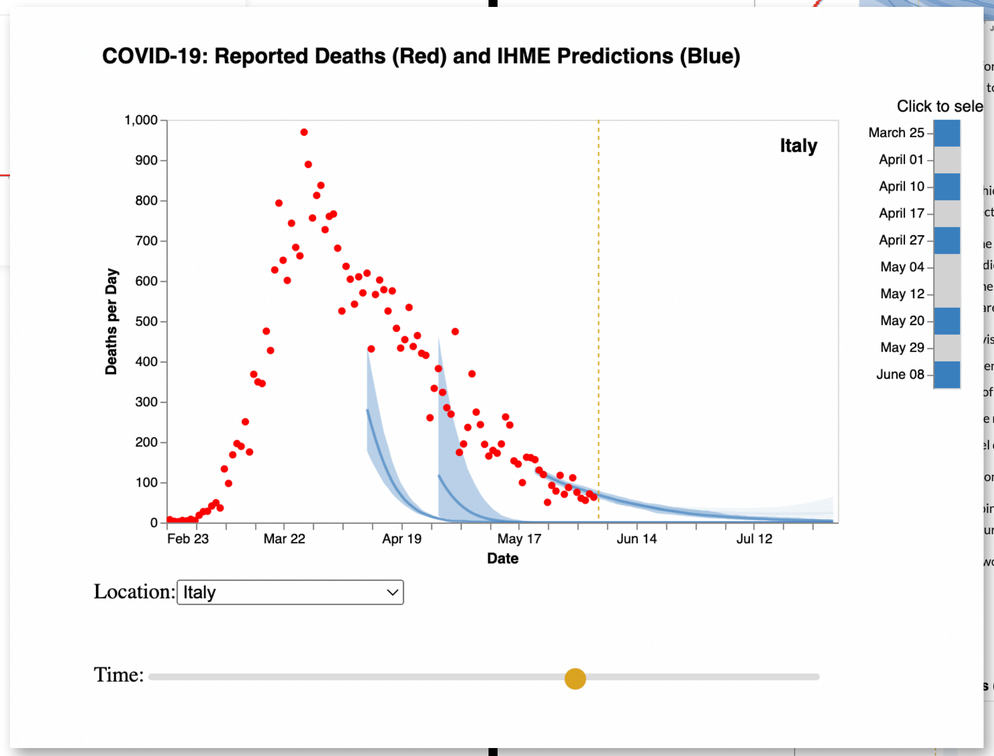


Uncertain Risks

We know how to express **risk** and **uncertainty** with numbers, but people don't always take practical actions based on those numbers. **The COVID crisis brings this contrast into sharp focus.**



Read More



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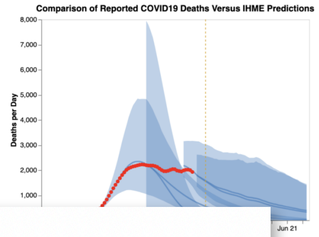
with many thanks to Immaculata De Vivo & Jonathan Foster

glue solutions inc. gluesolutions, inc.

Home Gallery Our Team The Software glue-con **Social Impact** Working with Us

Social Impact



IHME Model Uncertainty, Visualized over Time

The Institute for Health Metrics and Evaluation (IHME) creates, maintains, updates, and publishes an open-source statistical model of the impact of the COVID-19 pandemic, based on open-data resources. As a public service, glue solutions, inc. here offers an online tool for visualizing the evolution of the IHME models over time.

The general public has seen many versions of the IHME "Daily Deaths" plots, including in several White House briefings. Our goal here is to offer a look at **how the models change**—appropriately, in response to new data and information—over time, and how that affects model updates. In a companion essay online at the Prediction Project site, we offer more context on why this evolution is so interesting.

(Banner above shows sample IHME "Daily Deaths" graphic, from 14 May 2020.)

or 4
tools

hics below, you can re-create the display of deaths/day akin to what would have been visible at IHME's COVID-19 web site on a ct. In addition, you can show more than one model (date) at a time, to make comparisons.

e panels below: **red** dots show reported *actual* deaths per day; solid **blue** lines show forecasts, and light **blue shaded** regions show dicate ranges of possible outcomes, as forecast on the date when the model was made. The ranges should account for 95% of e time slider below each graph, the model and its associated uncertainty band change over time. As more and more models are re regions where models have been most consistent.

isualization offered below. They are as follows (with source links in [brackets]):

entative model dates. [source, GitHub] [mobile site]

f model dates [source, GitHub]

e model dates [source, GitHub] [mobile site]

l dates [source, GitHub]

on "glue solutions, inc." Static graphics can be extracted using the three dots at the upper right of each graphic.

in the discussion at the 10QViz.org IHME COVID-19 Model Uncertainty Visualization page to upload your graphic and tell the ur graphic using the three dots at the top right of each panel below.)

work best on larger screens. We provide links to standalone views of the visualization showing 4 representative model dates that

IHME Models over time, for the United States, for 4 representative dates

Mobile-optimized visualization

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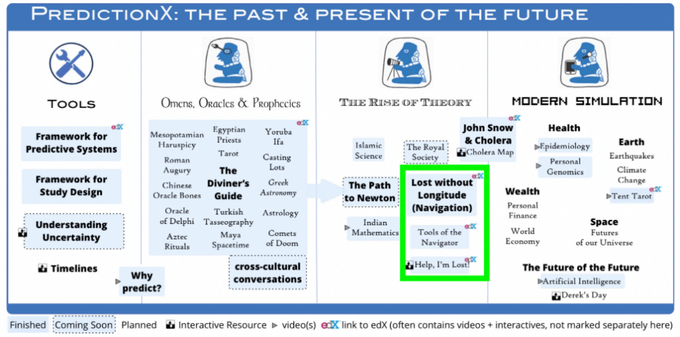
natural phenomena.

Learner's GUIDE to Lost Without Longitude

Overview: The **Prediction** project is an ongoing study of how humanity has predicted the future, from antiquity to the present. *Lost without Longitude* is a module within the Prediction project that focuses on the connection between prediction and navigation and why longitude was, for millennia, so difficult to measure. The module is a piece of the larger edX offering known as "PredictionX," which includes content like PredictionX: Diviner's Guide and PredictionX: John Snow and the Cholera Outbreak of 1854.



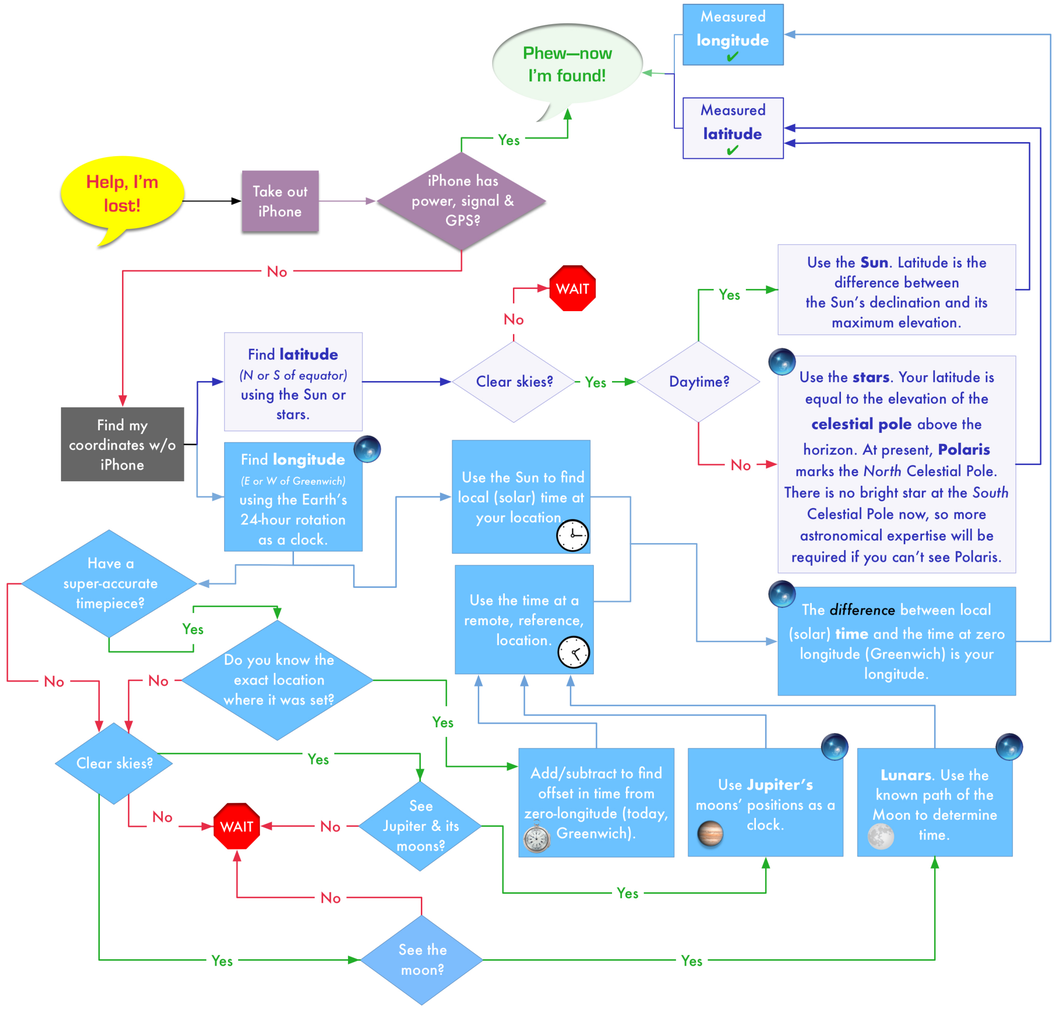
Structure: In *Lost Without Longitude*, we combine text, infographics, interviews with experts, and videos made using WorldWide Telescope to explore the tools and techniques navigators have used throughout history, with a particular focus on the importance (and difficulty) of measuring longitude. By studying the following pages, watching interviews with experts, and experiencing digital tours of the solar system, you will learn how to use the sky, time, and a number of special instruments so that you can find your way no matter where you are.

Lost Without Longitude offers a ten question final exam. If you get 8 or more questions right, you can earn a certificate. (Even if you do not want a certificate, the exam is a good place to test your knowledge on the key aspects of the course).

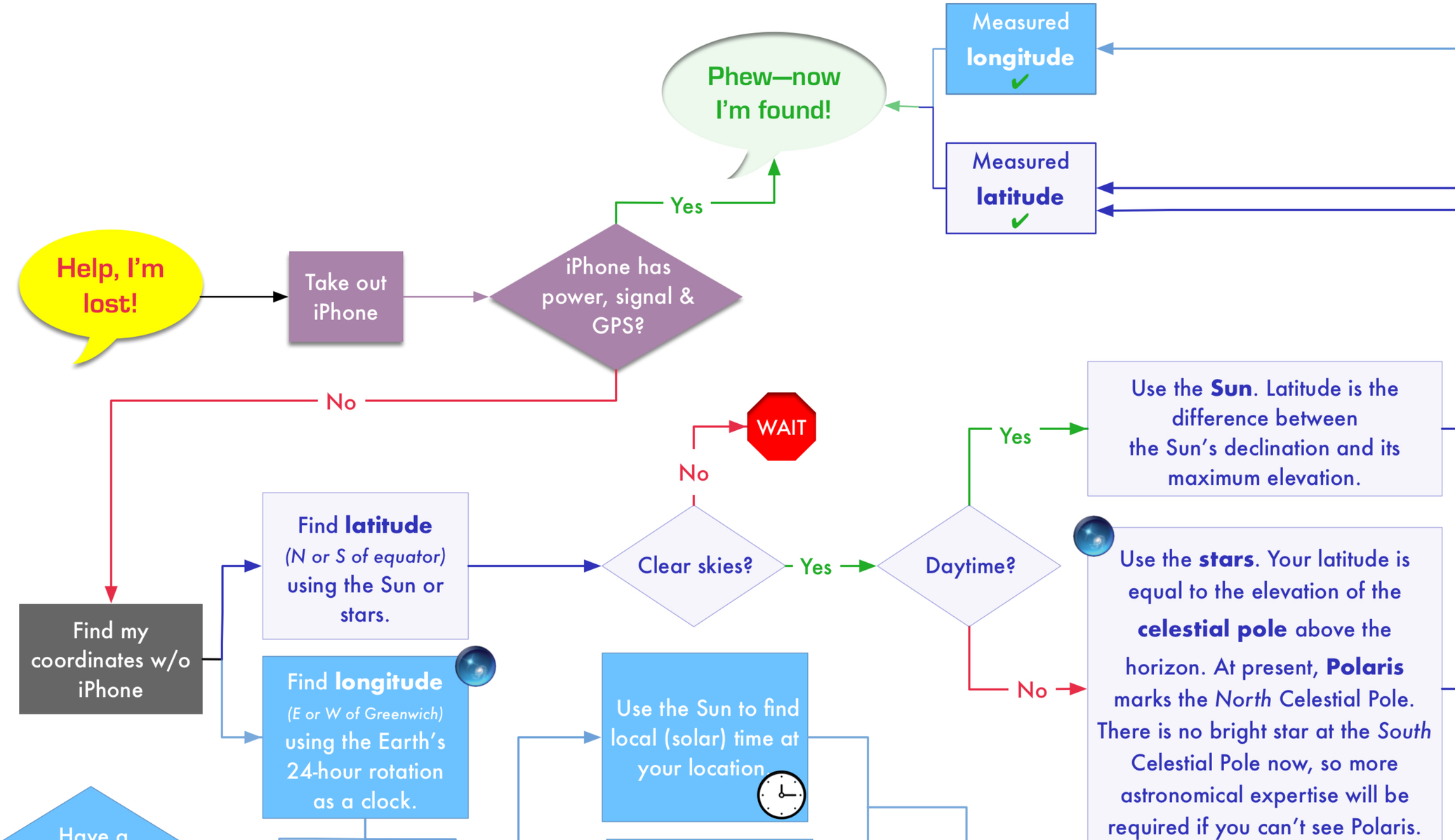
If you have any questions or thoughts on the course, please feel free to post in the discussion forum.

How to use the material: On this "guide" page, we offer you quick and easy links to all the course materials. Essentially, you can think of this guide as the "homepage" of a web site, and you're welcome to use it in lieu of the standard edX navigation tools if you prefer. We suggest going through the material in the order it's presented in numerical order below, but you can also skip around as you like.

“Lost without Longitude”



“Lost without Longitude”



Earth as a Clock

The Celestial Sphere

Jupiter’s Moons

Latitude & Longitude

Lunars on the Sky

Why Lunars are Hard

PATH TO

A project to track the evolution of science

TRY THE PATH TO NEWTON

path-to.org

SEEING THE FUTURE

OF THE UNIVERSE, DATA, LEARNING, AND DIGITAL SCHOLARSHIP

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SALE
$59.99
THE CUBE
MOUSE
HUMAN
DATA
Integrate mouse and human data to construct a predictive model of a human disease
Type 2 (Adult Onset) Diabetes
uman Proposition
Experimental and Data Output: 2019-2021
The Jackson Laboratory (JAX): Preparing for the future of Biology
Streamers Bridge the Gap
Searching for the OH Zeeman Effect in Star-Forming Clouds
an Probe The Extent of the Milky
nsler (University of Toronto)
Protostellar Environm
Culture of Publishing
Dissociation Region Toolbox
radio-astro-tools
spectral-cube

SEEING THE FUTU

OF THE UNIVERSE, DATA, LEARNING, AND DIGITAL SCHO

“PART 2”

THANK YOU ALL SO VERY MUCH!

SEEING THE FUTURE

OF THE UNIVERSE, DATA, LEARNING, AND DIGITAL SCHOLARSHIP

RT 2”

CATHERINE!!

Special thanks to Phil & Alex for the “Refreshments…”

Participant List

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Charles Alcock
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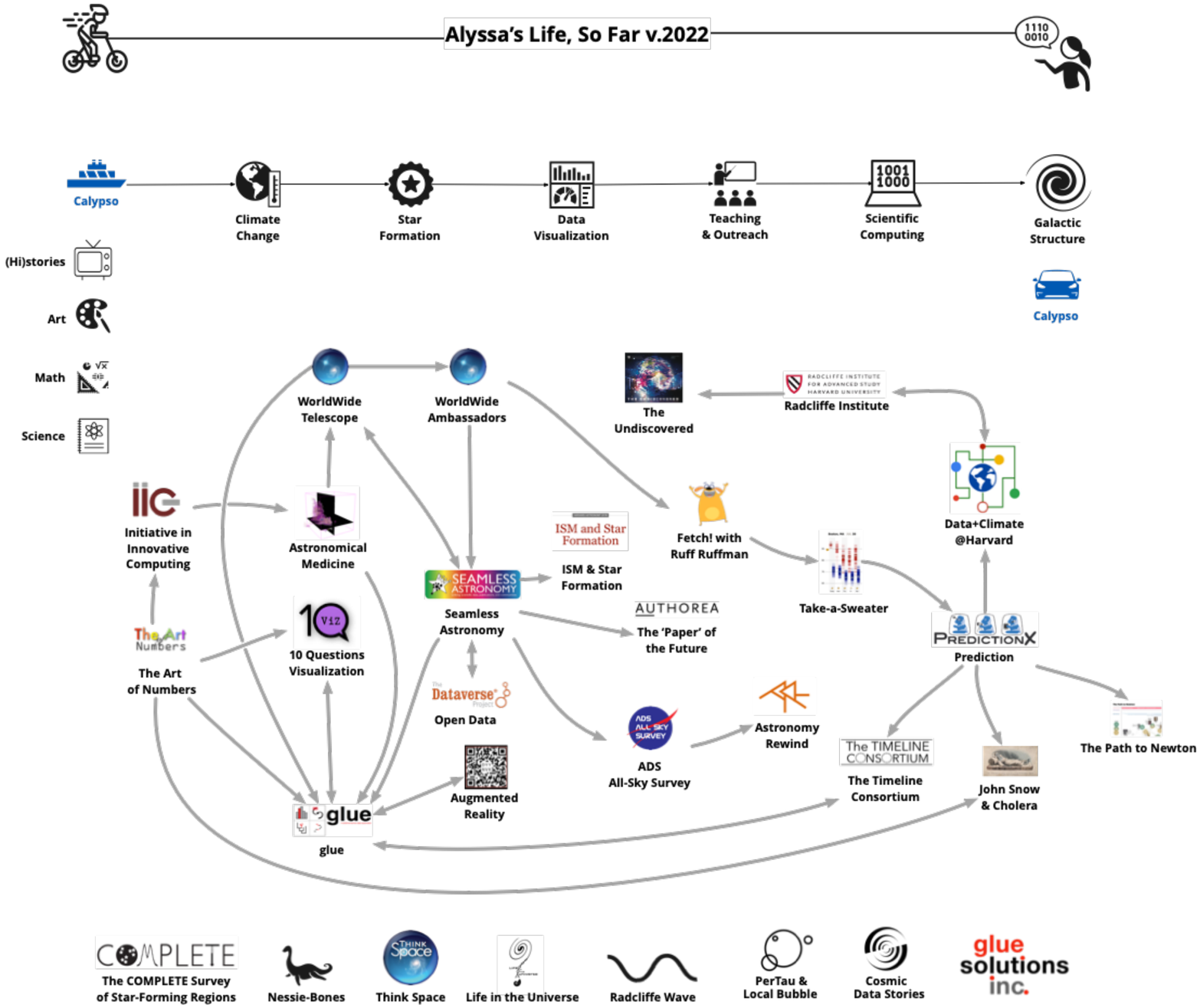
Ronald Stark
Mark SubbaRao
Susan Sunbury
Jonas Syed
Erik Tollerud
Anne Trefethen
Thomas Troland
Patricia Udomprasert
Annie Valva
Enrique Vazquez-Semadeni
Jennifer Wallace
Peter Williams
David Wilner
Qizhou Zhang

You are all part of this crazy network—
THANK YOU!



The Path to Newton

PREVAILING BELIEF

TOOLS AVAILABLE

MATH AVAILABLE

CONCERNED WITH PHENOMENA

EARTH AT CENTER (⊙ BELIEVED SUN AT CENTER)

GNOMON

GNOMON
ASTROLABE

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

ARITHMETIC
ZERO AS PLACE HOLD
PLANAR GEOMETRY
SPHERICAL GEOMETR
TRIGONOMETRY
SPHERICAL TRIGONO
SPRERICAL TRIGONOMETRY
ALGEBRA

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

Some "stars" move more than others

Astronomical Diaries

Natural, not supernatural.

THALES
624–546 BCE
Greek

Nature can be explained

Motion and change are illusions

Question all you "see."

PARMENIDES
515–450 BCE
Greek

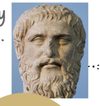
Motion needs a little push.

ANAXAGOROS
510–428 BCE
Greek

Motion must have a cause

SOCRATES
470–399 BCE
Greek

PLATO
427–347 BCE
Greek



Symmetry rules.

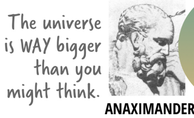
The air moves objects through it

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



The universe is WAY bigger than you might think.

ANAXIMANDER
610–546 BCE
Greek

Earth generated by boundless eternity

If circles are perfect, spheres are sublime.

PYTHAGORAS
570–495 BCE
Greek

Universe is spherical

Rearranging "atoms" allows motion

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

DEMOCRITUS
460–370 BCE
Greek

It's spheres all the way down.

EUDOXUS
390-337 BCE
Greek

Planets, Moon, Sun, move on spheres

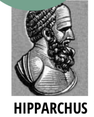
Earth is stationary center of the universe

ARISTARCHUS
310–230 BCE
Greek

Hello? Is this thing on?

Sun at center

Math can model the universe



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

HIPPARCHUS
190-120 BCE
Greek living in Rome

I can prove it!

EUCLID
300? BCE
Greek

A single framework for all geometry

Epicycles, equants, eccentrics

Circles ARE the best! We just need more!

PTOLEMY
100–170
Greek living in Roman Egypt

Motion caused by self-exhausting force

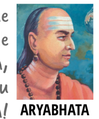
Celestial and terrestrial phenomena similar

Aristotle is wrong about space, time, and matter.

JOHN PHILOPONUS
490–570
Greek living in Roman Egypt

I must gather information for better astrolog and I shall shar what I learn!

VĀRĀHAMIHIRA
505–587
Indian



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

ARYABHATA
476–550
Indian

Sines improve accuracy

Who knew nothing could be so useful?

BRAHMA
598–
Indi

Zero
numb
unto i

On the Heavens
Aristotle
c. 350 BCE

Physics
Aristotle
c. 320 BCE

Elements
Euclid
c. 300 BCE

The Almagest
Ptolemy
c. 150

Aryabhatiya
Aryabhata
c. 499

On Aristotle's Physics 3
Philoponus
c. 520

Pañca-siddhāntikā
Vārāhamihira
c. 575

Brahmas siddha
Brahma
c. 62

SUN AT CENTER (⊕ BELIEVED EARTH AT CENTER)

GNOMON
ASTROLABE
PRINTING PRESS

ARITHMETIC
ZERO AS PLACE HOLDER
ZERO AS NUMERAL
PLANAR GEOMETRY
SPHERICAL GEOMETRY
TRIGONOMETRY
SPRERICAL TRIGONOMETRY
ALGEBRA
TUSI COUPLE AND OTHER SPECIAL FORMS
LOGARITHMS

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

RISTOTLE
3–322 BCE
Greek

All things move to their natural place

I can prove it!

EUCLID
300? BCE
Greek

A single framework for all geometry

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

Years from now, Copernicus will love me.

AL-BATTANI
858–929
Arab

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

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

What did Aristotle really mean? We need to question.

IBN RUSHD (AVERROES)
1126–1198
Arab

Motion is a chain of an object's locations

Bigger observatories, better observations.

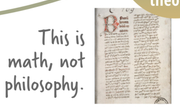
AL-TUSI
1201–1274
Persian

Simple circular orbits work with better math

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

NICOLE ORESME
1320–1382
French

Objects are "set into" motion



This is math, not philosophy.

JEAN BURIDAN
1295–1358
French

Motion explained with "impetus theory"

With giant spendy instruments, I can get GREAT data.

Math first, philosophy later.

NICHOLAS COPERNICUS
1473–1543
Polish

Sun at center of Earth's & planets' orbits

Planets orbit the Sun, but Sun orbits Earth

TYCHO BRAHE
1546–1601
Danish

Jupiter has moons, which orbit like our Moon

I have Tycho's fancy data!

Hmm... circles are a problem.

JOHANNES KEPLER
1571–1630
German

Orbits are ellipses, not circles

Hello? Is this thing on?

ARISTARCHUS
310–230 BCE
Greek

Sun at center

Math can model the universe

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

HIPPARCHUS
190-120 BCE
Greek living in Rome

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

ARYABHATA
476–550
Indian

Sines improve accuracy

Who knew nothing could be so useful?

BRAHMAGUPTA
598–668
Indian

Zero is a numeral unto itself

If I use a teeny unit of time...

BHĀSKARA II
1114–1185
Indian

Much of what we today call calculus

Earth need not be at rest, Ptolemy!

ALI QUSHJI
1403–1474
Turkic

The Earth might actually rotate

I can improve Ptolemy! To the printing press!

REGIOMONTANUS
1436–1476
German

Epitome of the Almagest
Regiomontanus
1496

Physics
Aristotle
c. 320 BCE

Elements
Euclid
c. 300 BCE

The Almagest
Ptolemy
c. 150

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Aryabhata
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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

De Revolutionibus
Copernicus
1543

Astronomia Nova
Johannes Kepler
1609

Siderius Nuncius
Galileo
1610

© Harvard University

PREDICTIONX

SUN AT CENTER (⊕ BELIEVED EARTH AT CENTER)

GNOMON
ASTROLABE
PRINTING PRESS
TELESCOPE
ARITHMETIC
ZERO AS NUMERAL
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1473–1543
Polish

With giant spendy instruments, I can get GREAT data.

Planets orbit the Sun, but Sun orbits Earth

TYCHO BRAHE
1546–1601
Danish

Oooh, I like this Dutch spyglass!

Sorry, Aristotle, you're just wrong.

GALILEO GALILEI
1564–1642
Italian

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

RENÉ DESCARTES
1596–1650
French

We're gonna need better math.

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

ISAAC NEWTON
1642–1726
British

Metaphysics? Hooey! Give me evidence and math.

IBN AL-HAYTHAM
965–1040
Arab

Motion is a chain of an object's locations

This is math, not philosophy.

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1295–1358
French

Simple circular orbits work with better math

The Earth might actually rotate

Sun at center of Earth's & planets' orbits

Jupiter has moons, which orbit like our Moon

All bodies on Earth have (circular) inertia

GRAVITY GOVERNS ALL

Models matching data is paramount

If I use a teeny unit of time...

BHĀSKARA II
1114–1185
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Much of what we today call calculus

Earth need not be at rest, Ptolemy!

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I have Tycho's fancy data!

JOHANNES KEPLER
1571–1630
German

Hmm... circles are a problem.

Orbits are ellipses, not circles

Sun is the center

All bodies have inertia

I must make Newton publish!

EDMOND HALLEY
1656–1742
British

Some comets return, predictably

Kitāb al-Shifā'
Ibn Sīnā
c. 1020

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

Siddhānta Shiromani
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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

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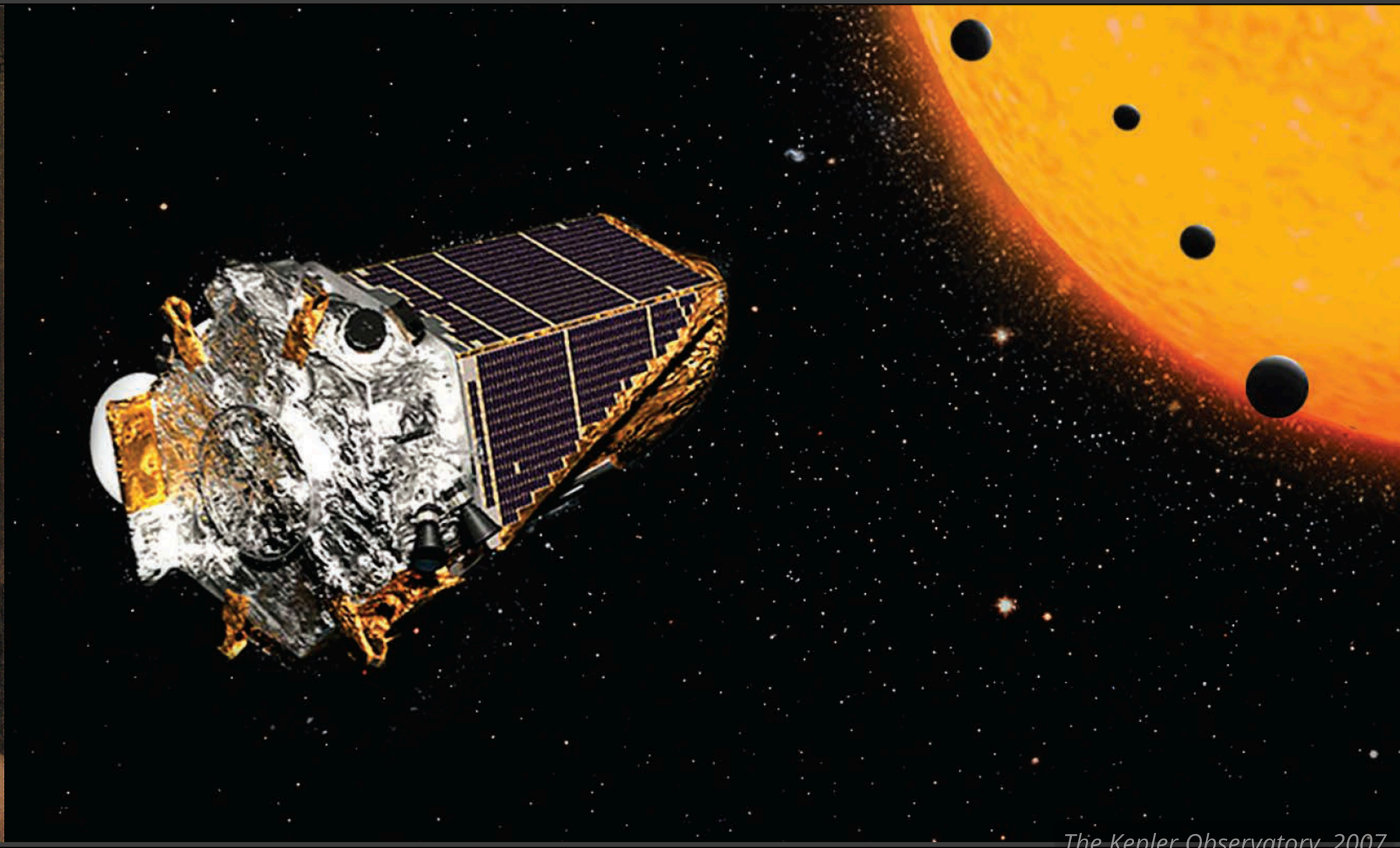
A lot can happen in “just” 435 years…

Johannes Kepler, 1571



The Kepler Observatory, 2007





Sort of a plan...

PAST | PRESENT | FUTURE

The TIMELINE CONSORTIUM

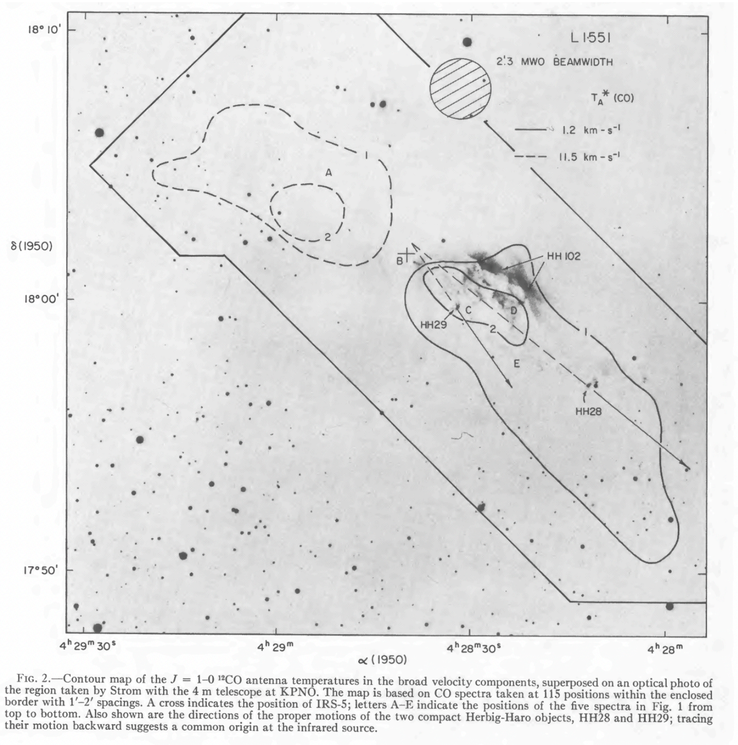
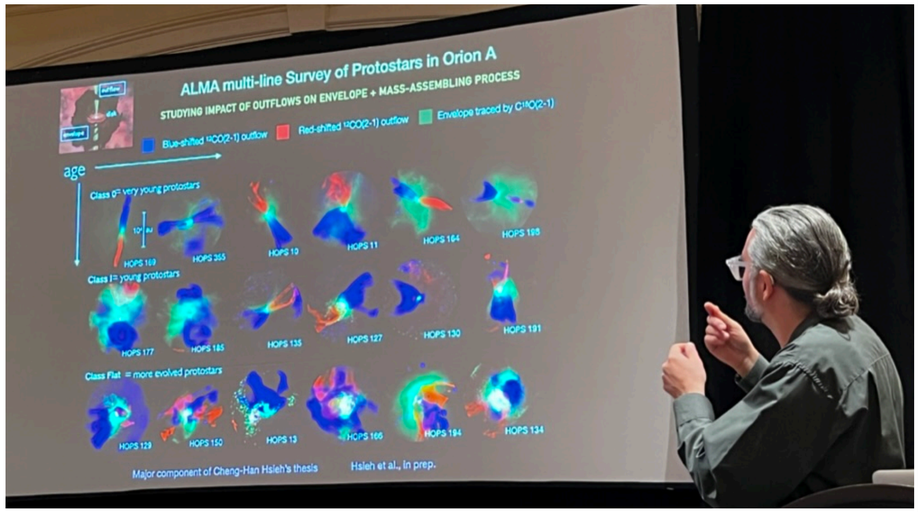


FIG. 2.—Contour map of the $J = 1$–0 ^{12}CO antenna temperatures in the broad velocity components, superposed on an optical photo of the region taken by Strom with the 4 m telescope at KPNO. The map is based on CO spectra taken at 115 positions within the enclosed border with 1'–2' spacings. A cross indicates the position of IRS-5; letters A–E indicate the positions of the five spectra in Fig. 1 from top to bottom. Also shown are the directions of the proper motions of the two compact Herbig-Haro objects, HH28 and HH29; tracing their motion backward suggests a common origin at the infrared source.

Snell et al. **1980**



Hsieh et al. **c. 2022**

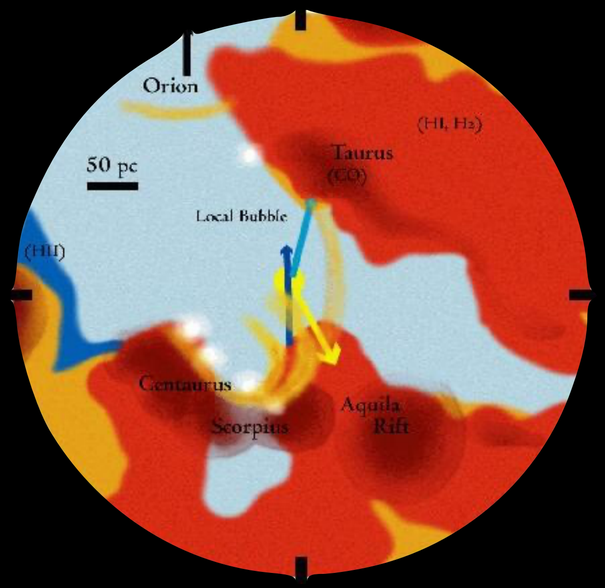
simultaneous accretion (from/along filaments) and excretion (by outflows and winds)

(more) **temporally**-resolved observations on disk scales

simulations — WITH magnetic fields and feedback — from "galaxy" to "filament" to "core" to "disk" to "planet" **scales**

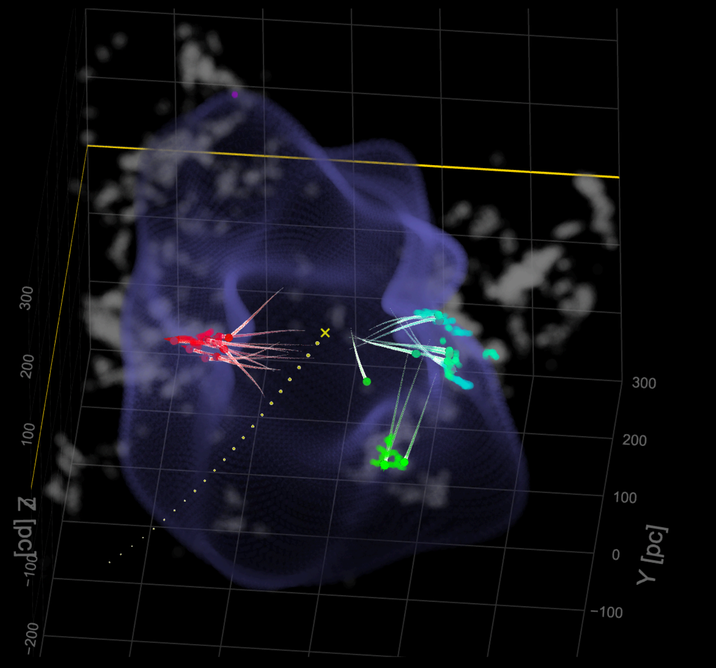
Image from VISIONS, Meingast et al.

PAST | PRESENT | FUTURE



Priscilla Frisch c. **1990s**, 2002 & earlier

PAST



Play Backward
Play Forward
Pause

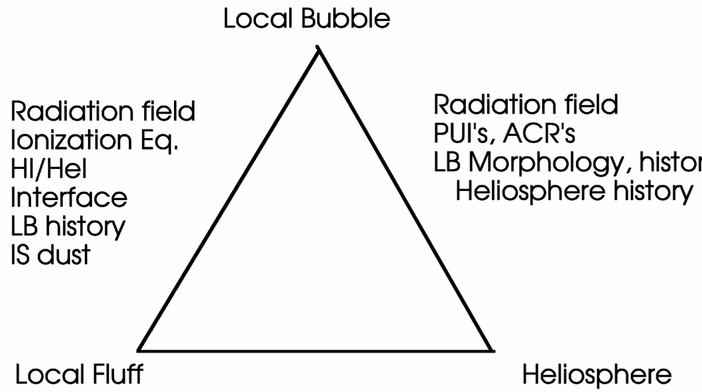
Traceback Time:

Present -2 Myr -4 Myr -6 Myr -8 Myr -10 Myr -12 Myr -14 Myr

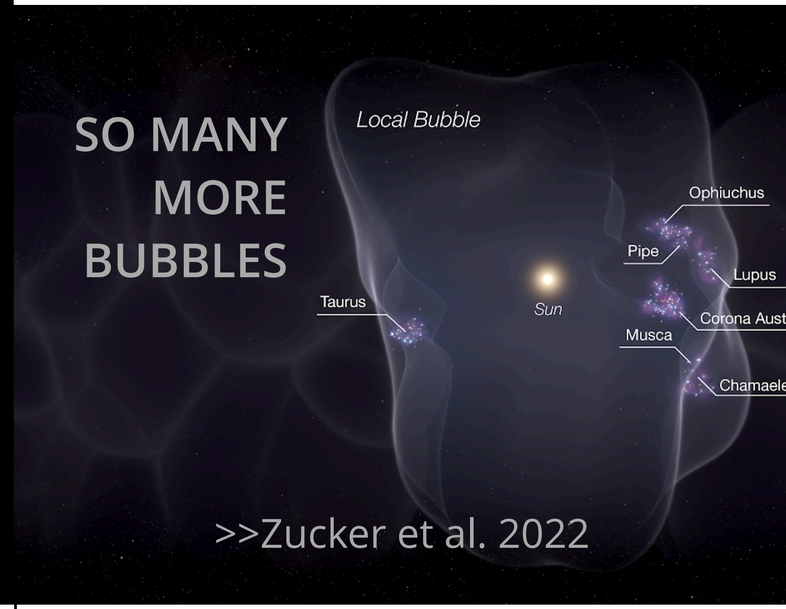
Zucker et al. **2022**

PRESENT

Frisch 1998—> Opher et al. 2022

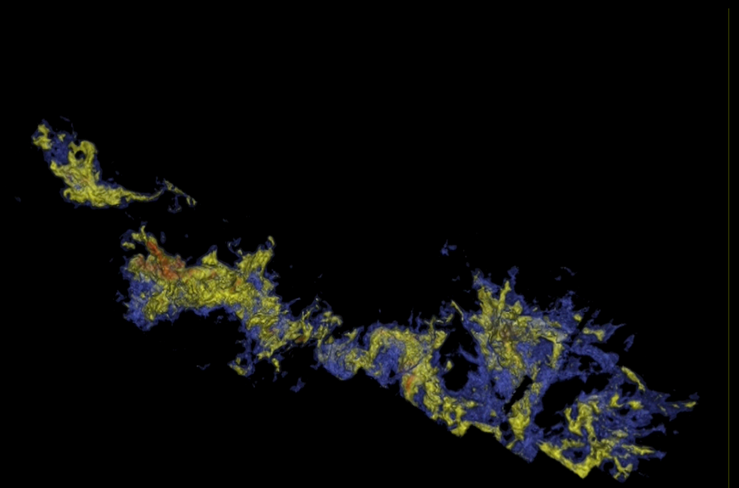


IS Neutrals, PUI's, ACR's
IS Pressure, HI Wall
IS Ionization Eq, PUI's, ACR's
IS Pressure, Velocity, HS Bowshock
HI, HeI Interplanetary Glows



>>Zucker et al. 2022

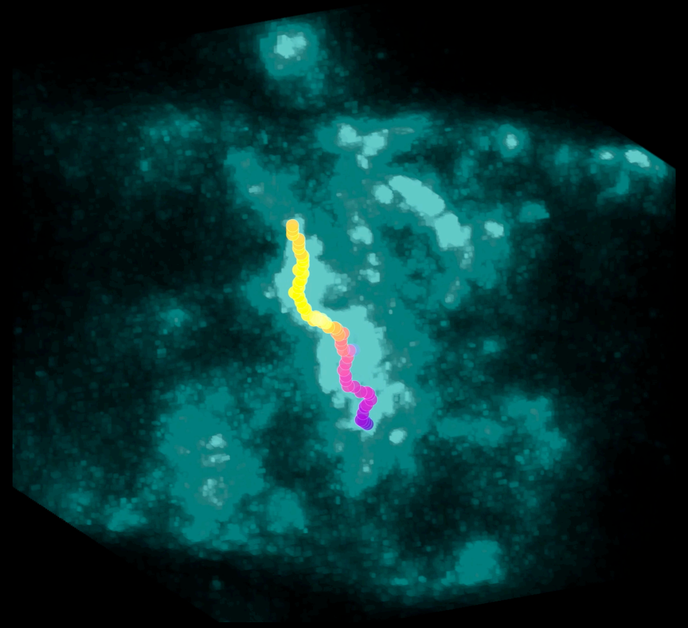
FUTURE



COMPLETE

Fake (p-p-v) 3D
c. 2006

PAST



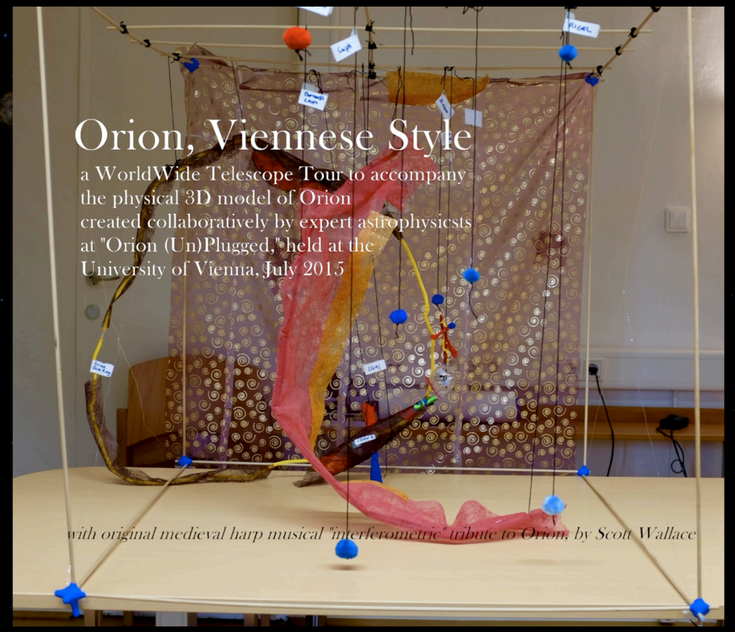
Real 3D
Zucker et al. **2020**

PRESENT

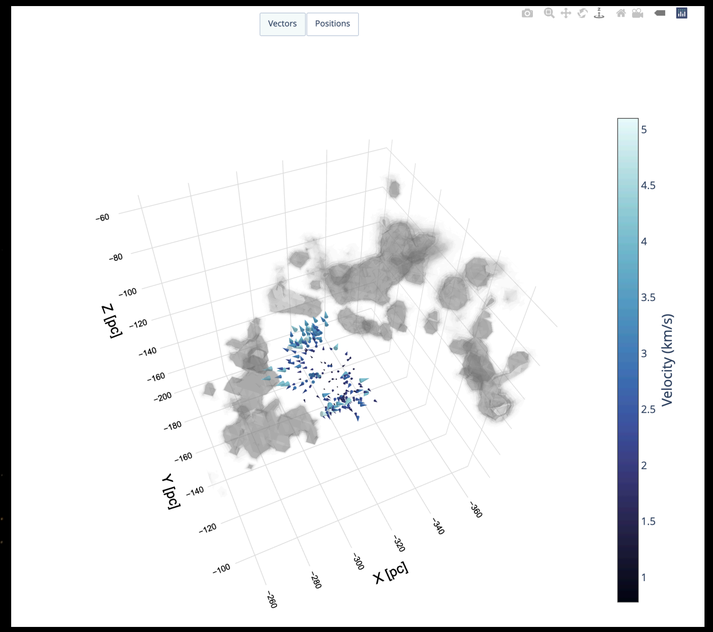
OpenSpace

Immersive (AR?) 6D,
with magnetic fields...

FUTURE



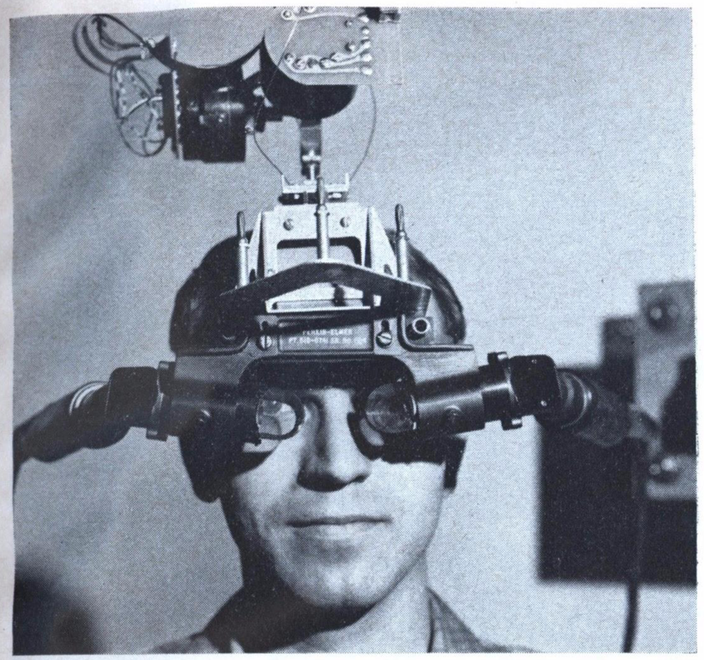
Vienna Meeting, thanks Joao Alves et al.
2015 (thanks to Felice Frankel)



Swiggum et al. **2021**; Foley et al. 2022
glue→plot.ly by C. Zucker

"All the Bubbles" and much more,
using Digital Universe, glue,
OpenSpace, WWT at
AMNH/Hayden Planetarium
late 2022, and beyond!

PAST | PRESENT | FUTURE



3-D trip inside a drawing, via computer graphics

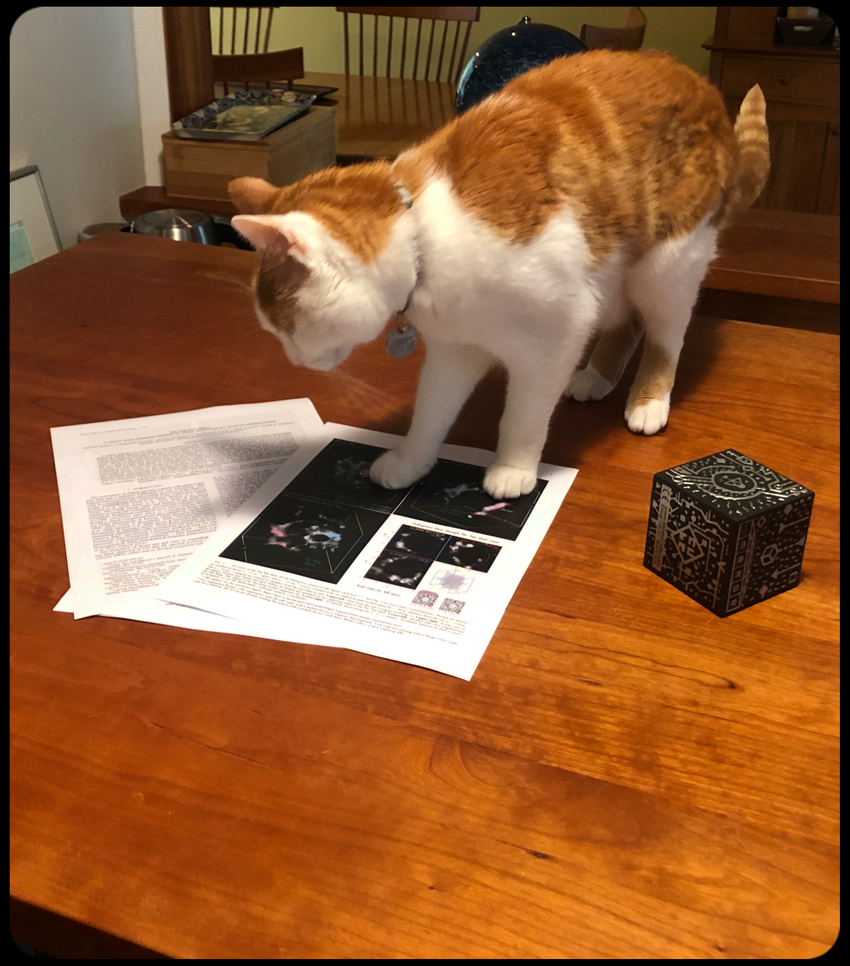
Slip this display device on your head and you see a computer-generated 3-D image of a room before your eyes. Move your head and your perspective changes, just as though you were actually inside the room. Architects could use the device to draw buildings in three dimensions; realtors could use it to show buyers the interiors of h… the office. Dr. Ivan Sutherland, U… the device, essentially a comput… version of the old stereoscope.

The Ultimate Display

Ivan E. Sutherland

Information Processing Techniques
Office, ARPA, OSD

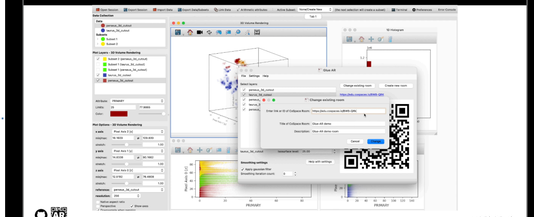
Sutherland 1965



see Bialy et al. 2021

Organization
Harvard
AAS
Northeastern
Johns Hopkins University & STScI
Delightex (US)
U. of Apld. Science & Arts NW (Switzerland)

AR PROTOTYPE AUTOMATED OUTPUT FROM GLUE…*



VIDEO DEMO

*thanks again to Delightex, Dr. Catherine Zucker plus Prof. Arzu Çöltekin & her students Luca Fluri and Andreas Ambühl at Fachhochschule Nordwestschweiz

2022??

PAST | PRESENT | FUTURE

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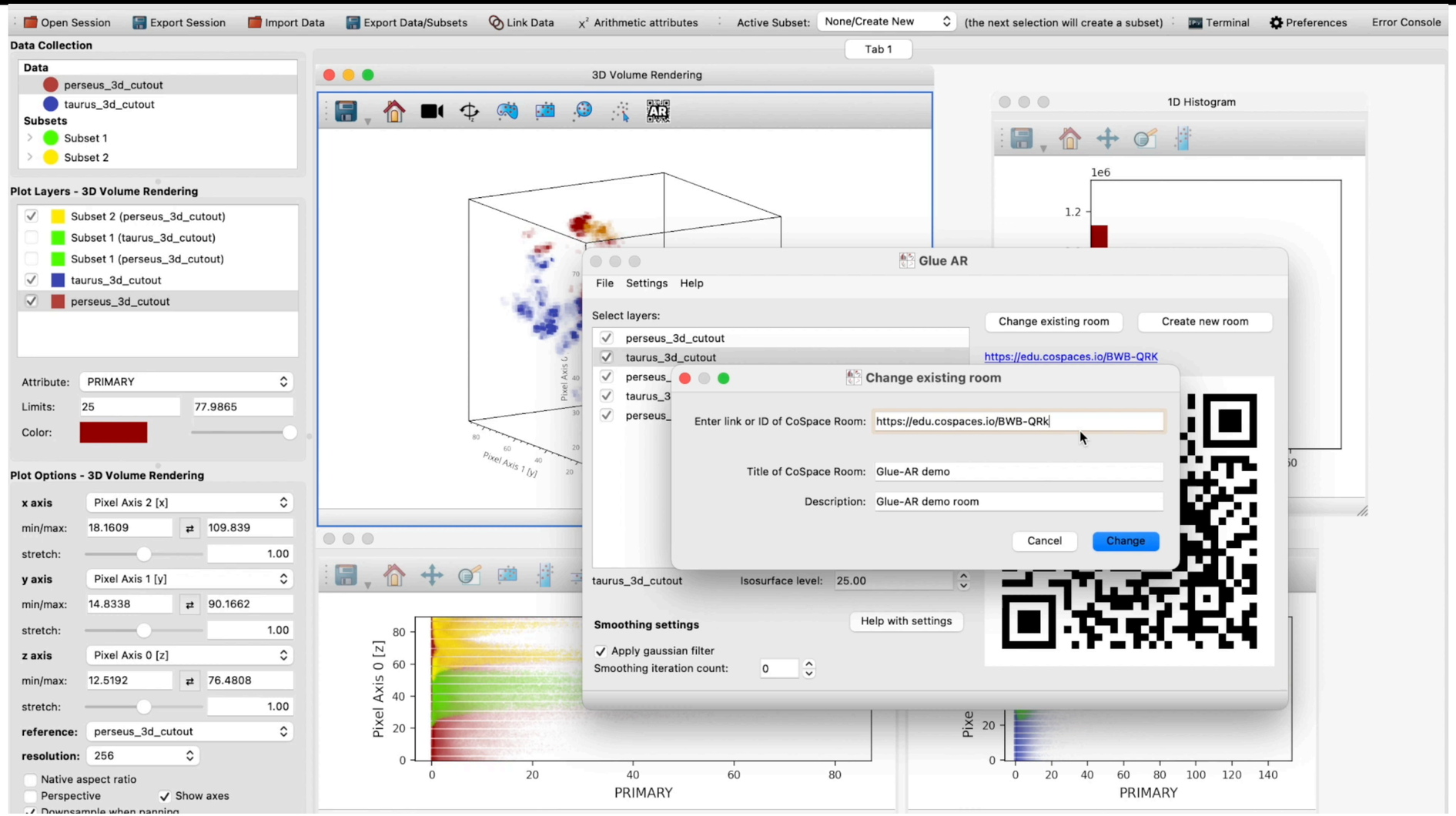

VIDEO DEMO

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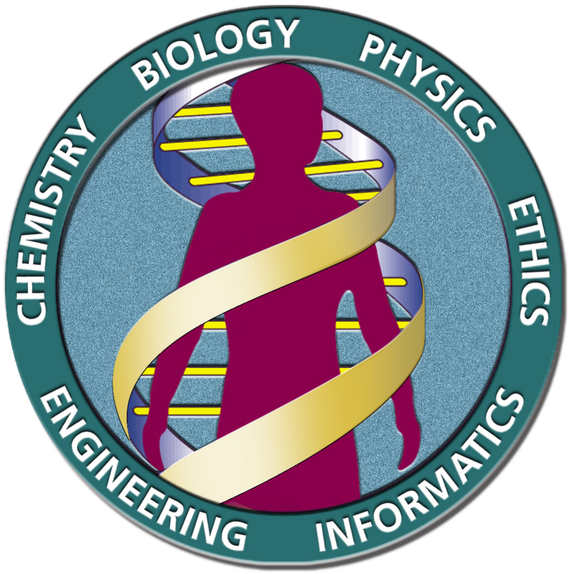
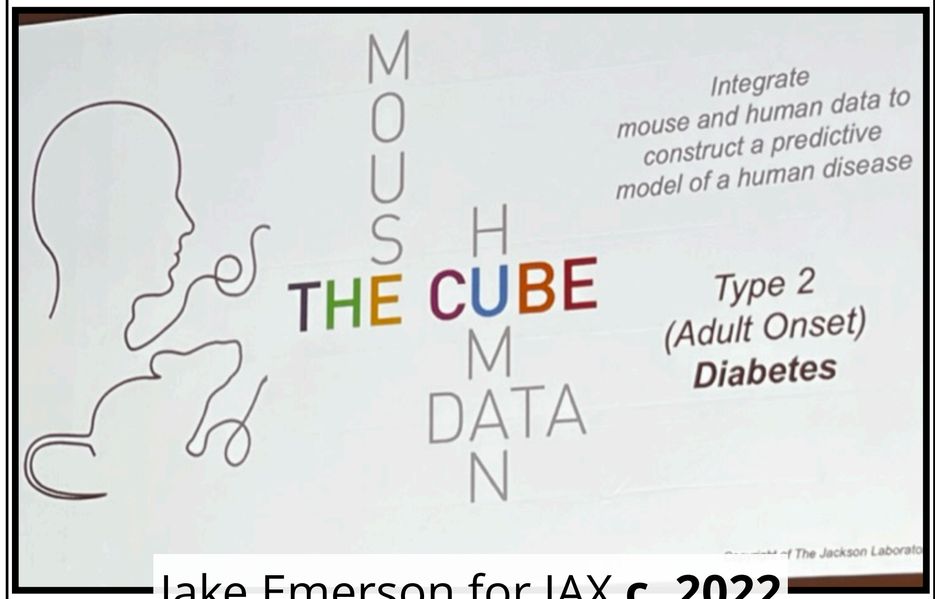
The Human Genome Project



1990-c. 2001

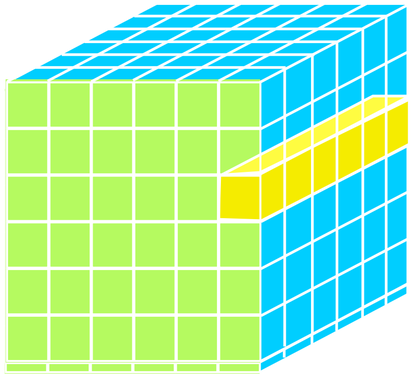
“The CUBE” & glue genes

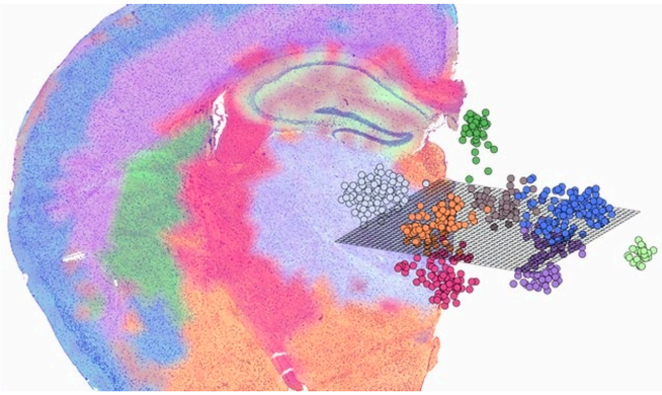


Jake Emerson for JAX **c. 2022**

glue genes

Spatial Transcriptomics





2022++

PAST | PRESENT | FUTURE

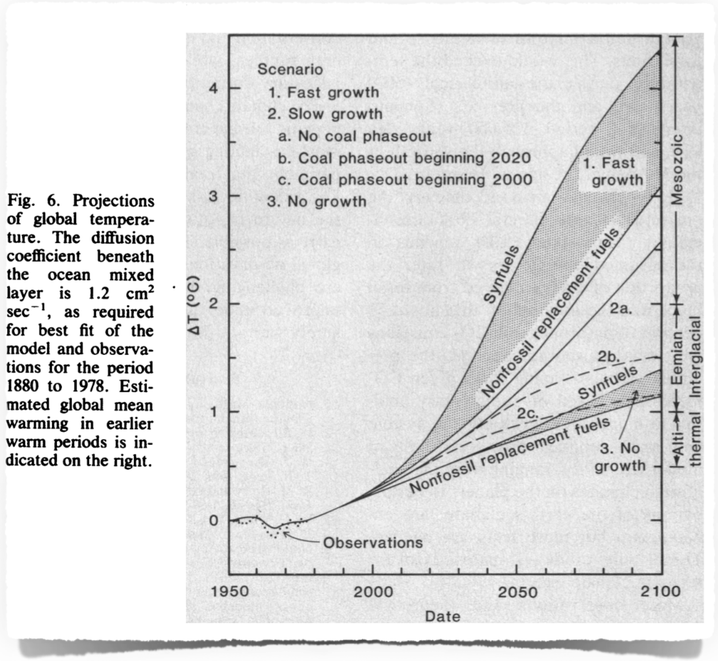
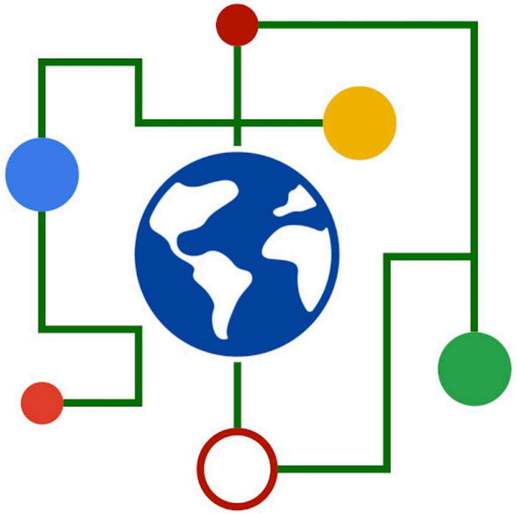


Fig. 6. Projections of global temperature. The diffusion coefficient beneath the ocean mixed layer is 1.2 cm^2 sec^{-1}, as required for best fit of the model and observations for the period 1880 to 1978. Estimated global mean warming in earlier warm periods is indicated on the right.

Hansen et al. 1981

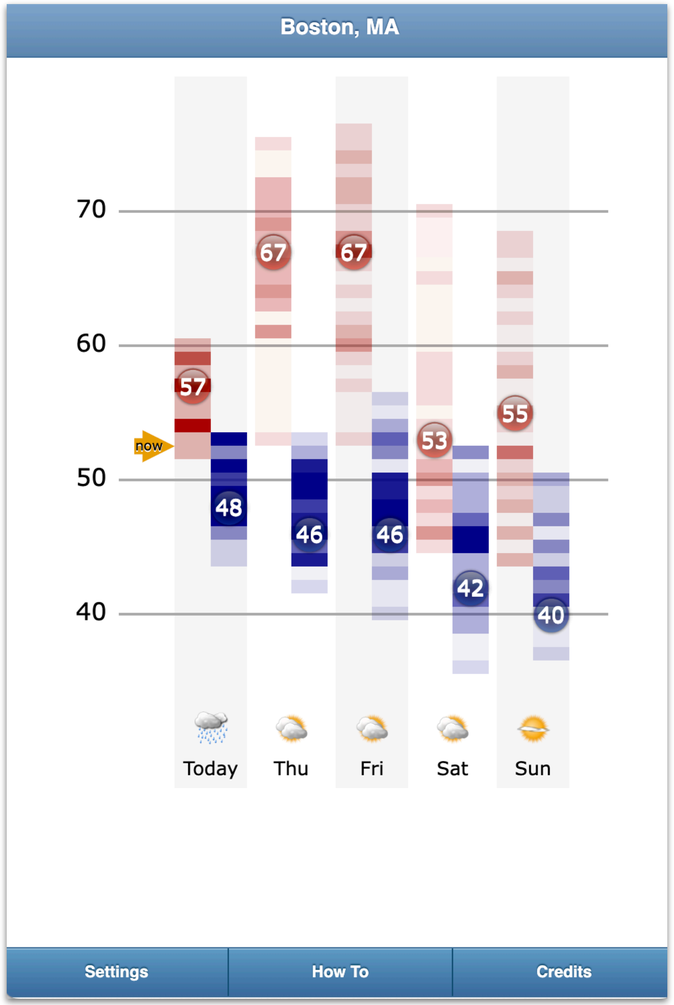


Data Commons.org
Data+Climate
@Harvard

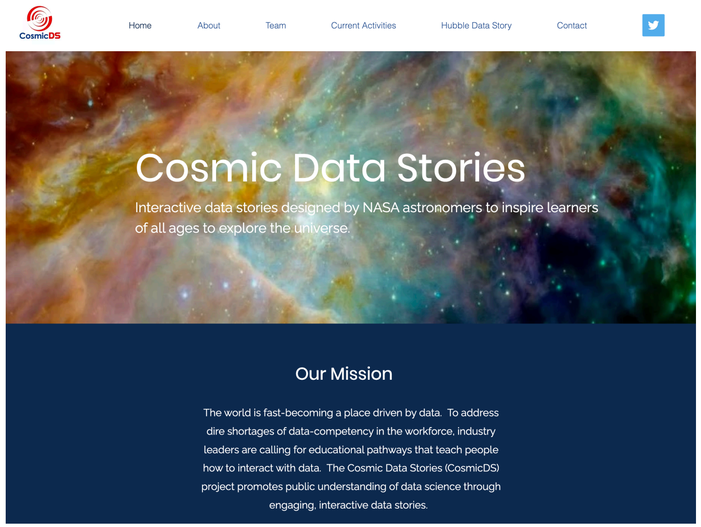
PAST

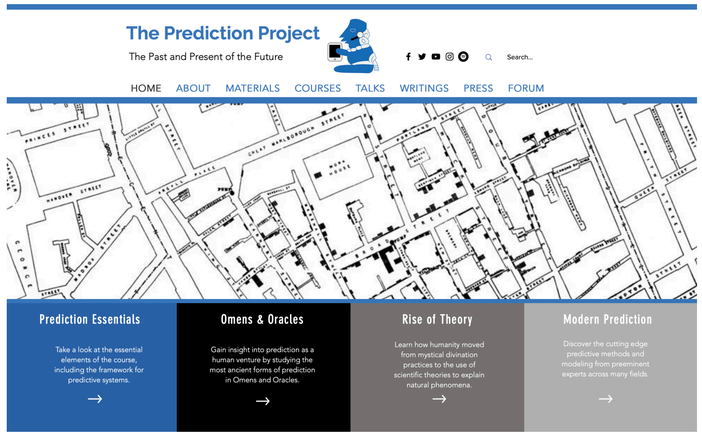
PRESENT

FUTURE

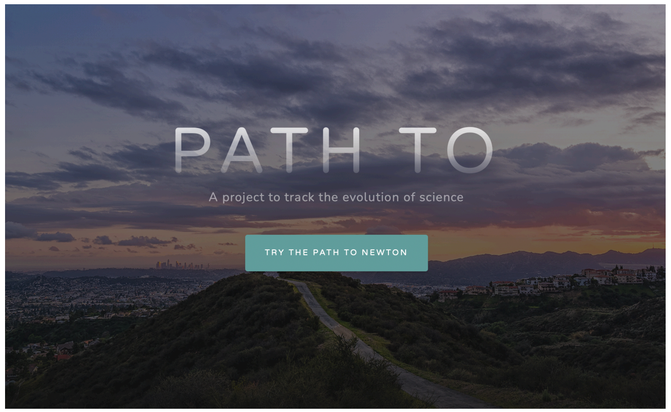


Take-a-Sweater.com 2012





CosmicDS, Prediction Project

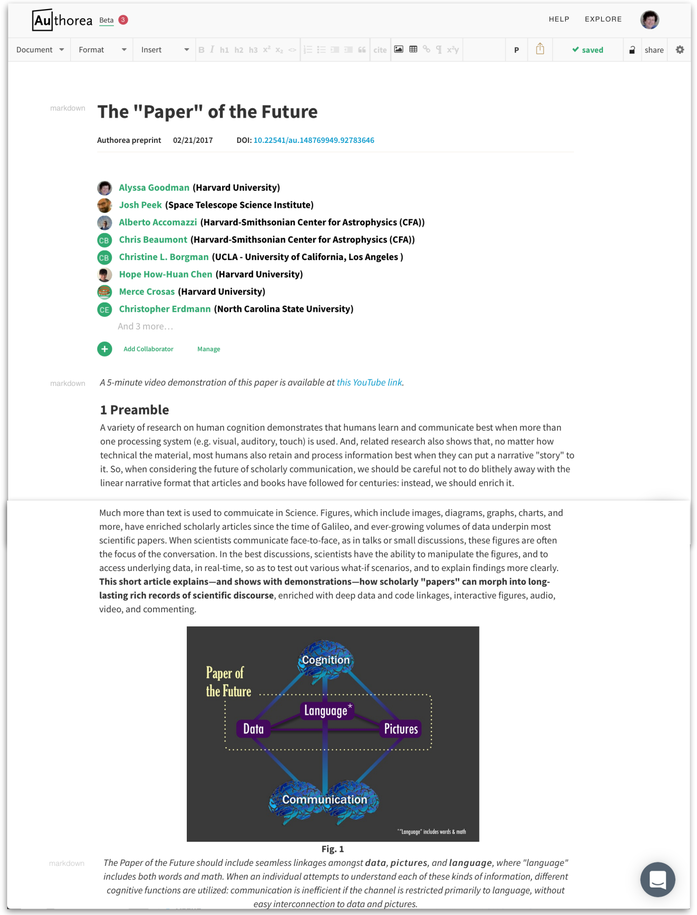


Path to Newton
Path to Einstein
Path to Darwin
Path to Modern Genetics

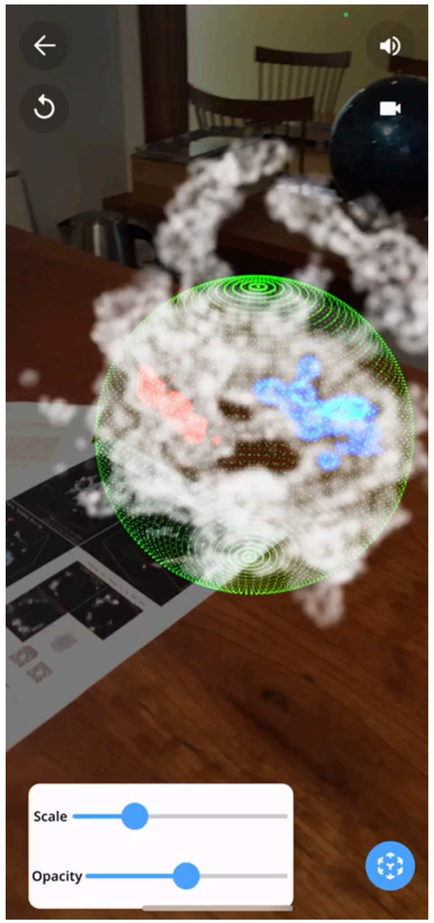
PAST

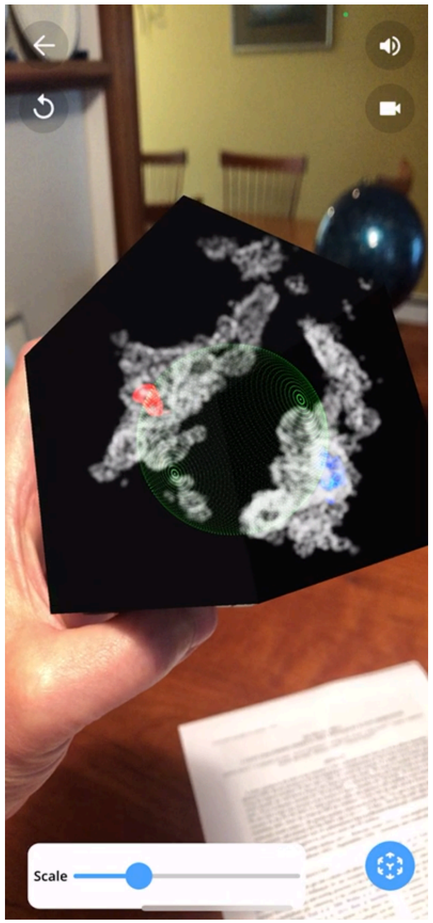
PRESENT

FUTURE

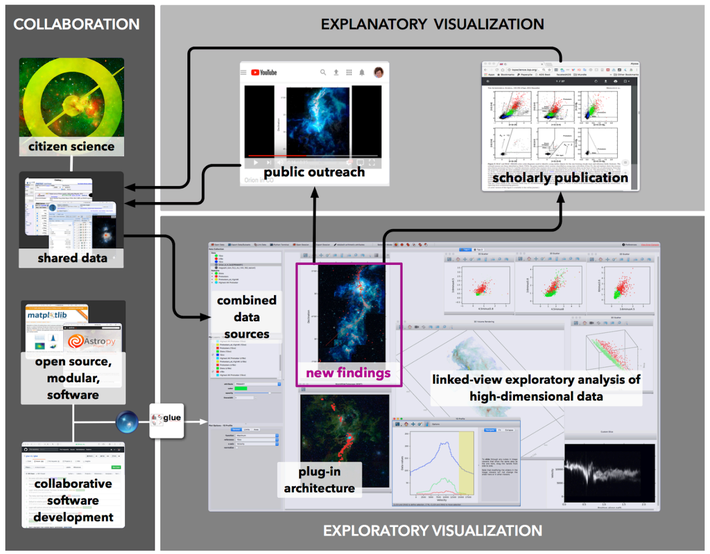


Goodman et al. 2015





Bialy al. 2021

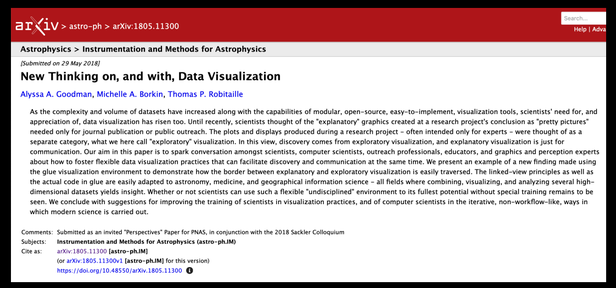


PAST

PRESENT

FUTURE

“New Thinking on, and with, Data Visualization”



arXiv > astro-ph > arXiv:1805.11300

Astrophysics > Instrumentation and Methods for Astrophysics

[Submitted on 29 May 2018]

New Thinking on, and with, Data Visualization

Alyssa A. Goodman, Michelle A. Borkin, Thomas P. Robitaille

As the complexity and volume of datasets have increased along with the capabilities of modular, open-source, easy-to-implement, visualization tools, scientists' need for, and appreciation of, data visualization has risen too. Until recently, scientists thought of the "explanatory" graphics created at a research project's conclusion as "pretty pictures" needed only for journal publication or public outreach. The plots and displays produced during a research project – often intended only for experts – were thought of as a separate category, what we here call "exploratory" visualization. In this view, discovery comes from exploratory visualization, and explanatory visualization is just for communication. Our aim in this paper is to spark conversation amongst scientists, computer scientists, outreach professionals, educators, and graphics and perception experts about how to foster flexible data visualization practices that can facilitate discovery and communication at the same time. We present an example of a new finding made using the glue visualization environment to demonstrate how the border between explanatory and exploratory visualization is easily traversed. The linked-view principles as well as the actual code in glue are easily adapted to astronomy, medicine, and geographical information science – all fields where combining, visualizing, and analyzing several high-dimensional datasets yields insight. Whether or not scientists can use such a flexible "undisciplined" environment to its fullest potential without special training remains to be seen. We conclude with suggestions for improving the training of scientists in visualization practices, and of computer scientists in the iterative, non-workflow-like, ways in which modern science is carried out.

Comments: Submitted as an invited "Perspectives" Paper for PNAS, in conjunction with the 2018 Sackler Colloquium
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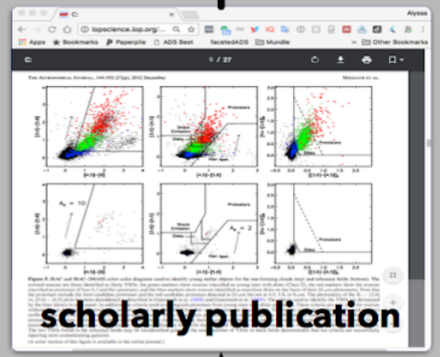
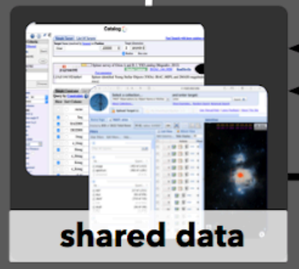
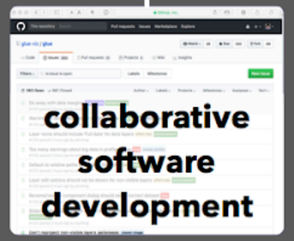
I promise to finish this soon!
(See arxiv for now, Goodman, Borkin & Robitaille 2018)

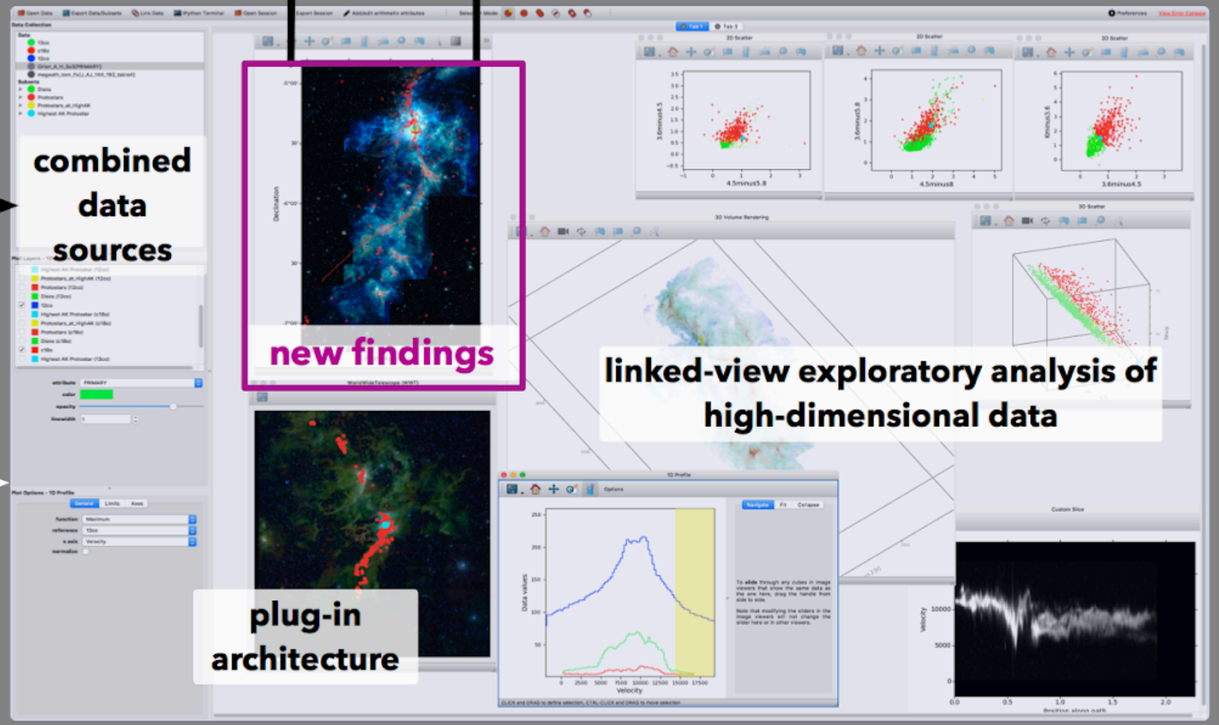
COLLABORATION

EXPLANATORY VISUALIZATION









EXPLORATORY VISUALIZATION

A travel tip...

Learn to use glue: Training, Videos, Demos

glue solutions offers a **variety of in-person and online training options** for new and experienced users of the glue, glupyter, and glue genes software environments, as well as associated plug-ins. On this page, we offer a sampling of videos and training materials developed to-date, both by glue solutions, and by the broader glue open-source community. Please do drop us a line if you'd like to see a demo or training not covered here!

Please note that additional helpful videos can be found at glueviz.org, the glue software project's home page.

Official glue software Documentation

The glue software project maintains a Documentation page, which offers information to help users get started, build custom plug-ins, and much more.

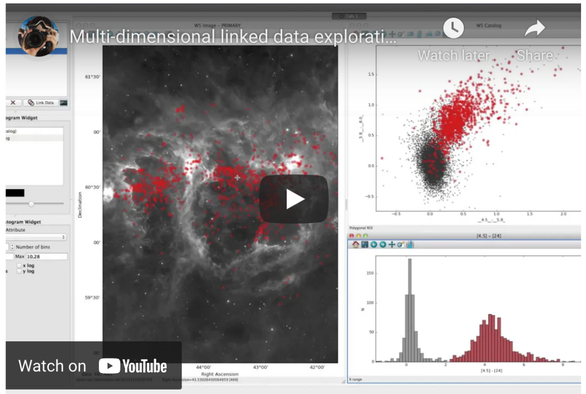
GitHub Repositories

For those who prefer readme files, and/or code, here are some handy links, within the glue-viz and gluesolutions orgs:

- glue GitHub repo
- glupyter GitHub repo
- glue genes GitHub repo

glue in 2 minutes

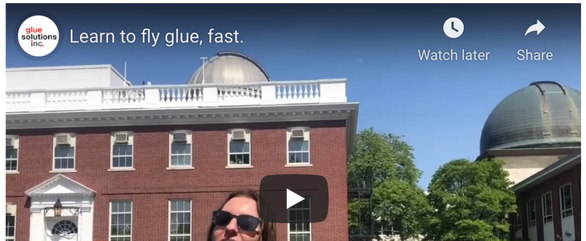
Entitled "Multi-dimensional linked data exploration with glue," this classic "early glue" video gives an overview of glue's most basic functionality--more of an intro than an actual tutorial. The "Airplanes over Boston," below for a short tutorial.



"Airplanes over Boston"

(Instructional Document, Data Set, and glue session files)

This short training uses a data set collected by glue solutions team members using a tiny USB antenna as an "observatory" to track air traffic over Boston from the roof of the Harvard-Smithsonian Center for Astrophysics. We are grateful to Harvard University for hosting the antenna, and *any data collected with it may be freely re-purposed. (This posting is pending approval from the National Science Foundation, which funds general-*



...think about dimensions,
(not just) glue.

And...

"Airplanes over Boston"

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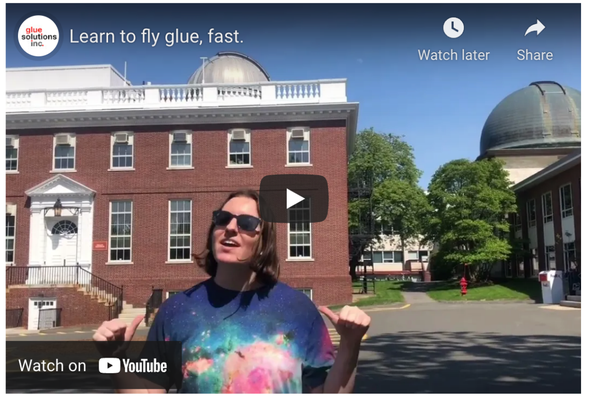


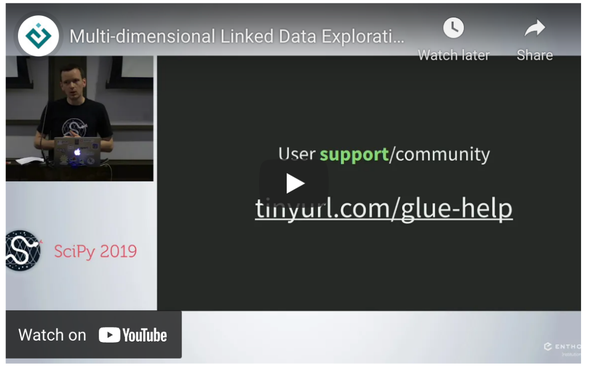
"Seeing More of the Universe" (YouTube playlist)

The **Seeing More of the Universe** Series was created by glue solutions' President, and Harvard Professor, Alyssa Goodman for the Data Science Fellowship Program of the Vera Rubin Observatory, in 2021. Goodman created these videos to help anyone interested in visualization--not just astronomers--learn more about how and why to visualize high-dimensional data. A full playlist is on the 10QViz YouTube channel, *free for re-use.*

Introduction to "Seeing More of the Universe", click here for the full series

Multi-dimensional Linked Data Exploration with glue

Lead glue developer Thomas Robitaille's 2019 glue tutorial at SciPy



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"If you got a dream, chase it,
‘cause a dream won’t chase you back.”

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