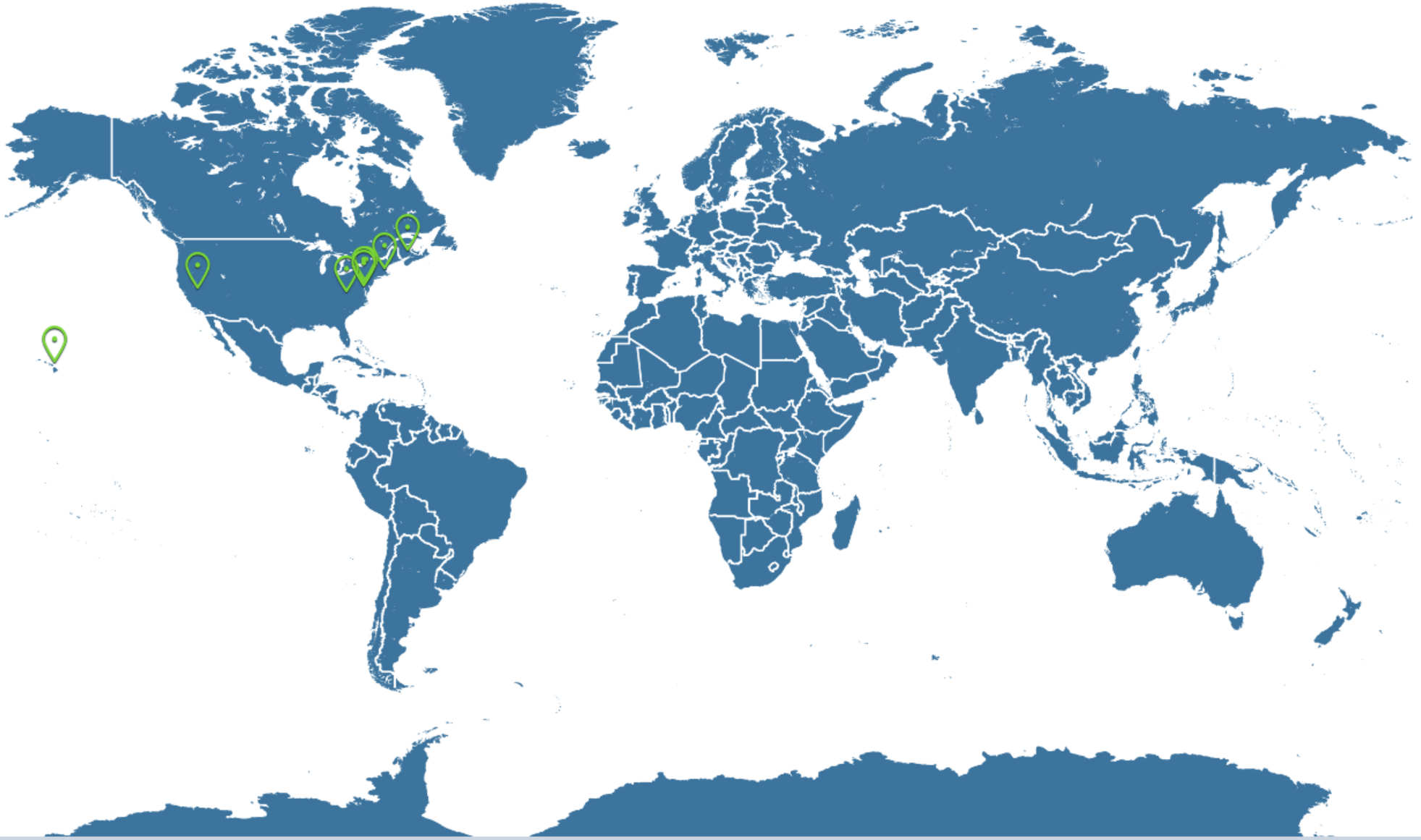

Your PRISE Universe, 2021
with Prof. Alyssa A. Goodman,Harvard Astronomy

Where I am right now...

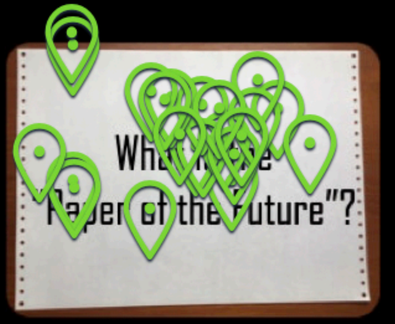


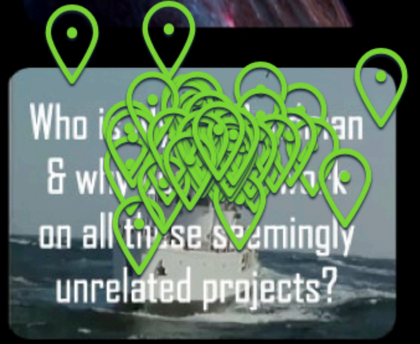
What are your areas of study? (up to 3, can include name of your concentration, or just your field of interest—but not TOO specific, please)

“ Neuroscience ” about 1 year ago	“ Immunology ” about 1 year ago	“ Geology ” about 1 year ago	“ Racial inequality ” about 1 year ago	“ Mathematics ” about 1 year ago	“ Government ” about 1 year ago
“ astronomy ” about 1 year ago	“ Sociology ” about 1 year ago	“ Chemistry ” about 1 year ago	“ Chemistry ” about 1 year ago	“ History of Science ” about 1 year ago	“ History of Science ” about 1 year ago
“ Electrical Engineering, Computer Science ” about 1 year ago	“ Biomedical engineering ” about 1 year ago	“ Math ” about 1 year ago	“ Math ” about 1 year ago	“ Engineering ” about 1 year ago	
“ physics ” about 1 year ago	“ Economics ” about 1 year ago	“ biology ” about 1 year ago	“ neuroscience ” about 1 year ago	“ Genetics ” about 1 year ago	“ Chemical and Physical Biology ” about 1 year ago
“ Neuroscience ” about 1 year ago	“ Human body ” about 1 year ago	“ entrepreneurship ” about 1 year ago	“ Disease ” about 1 year ago	“ Neuroscience ” about 1 year ago	“ Infectious Disease ” about 1 year ago
“ Biomedical engineering ” about 1 year ago	“ STEM ” about 1 year ago	“ Computational Biology ” about 1 year ago	“ Molecular and Cellular Biology ” about 1 year ago	“ astrophysics ” about 1 year ago	
“ healthcare economics ” about 1 year ago	“ data science ” about 1 year ago	“ Public Health ” about 1 year ago	“ Physics ” about 1 year ago	“ History ” about 1 year ago	“ Astrophysics ” about 1 year ago

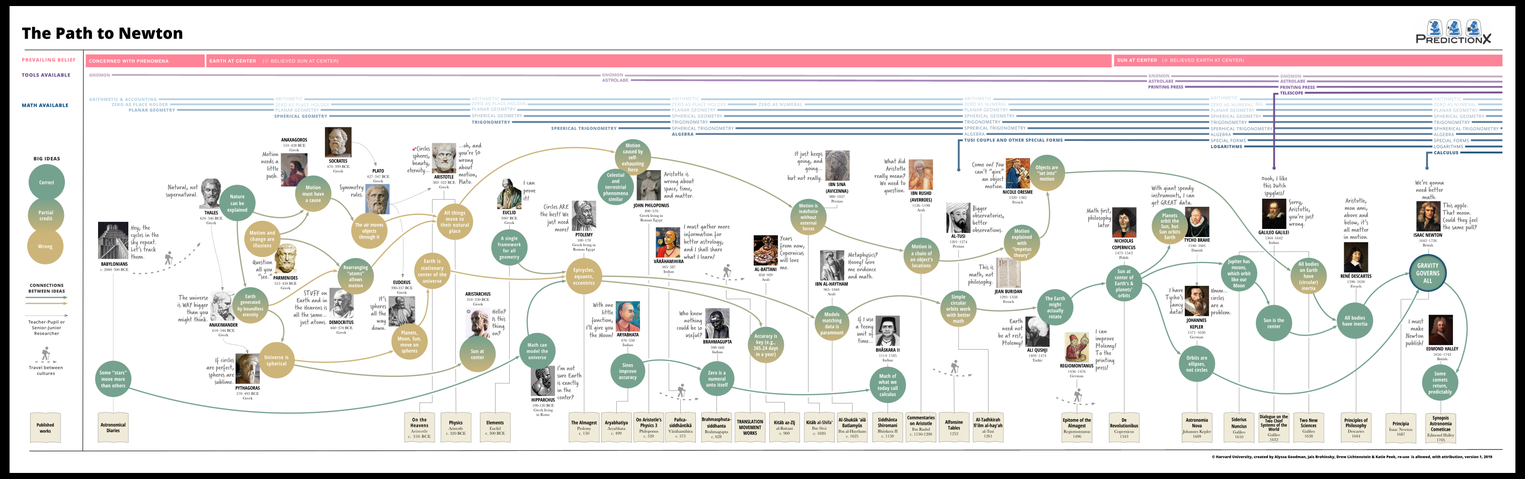
When poll is active, respond at **PollEv.com/prediction**

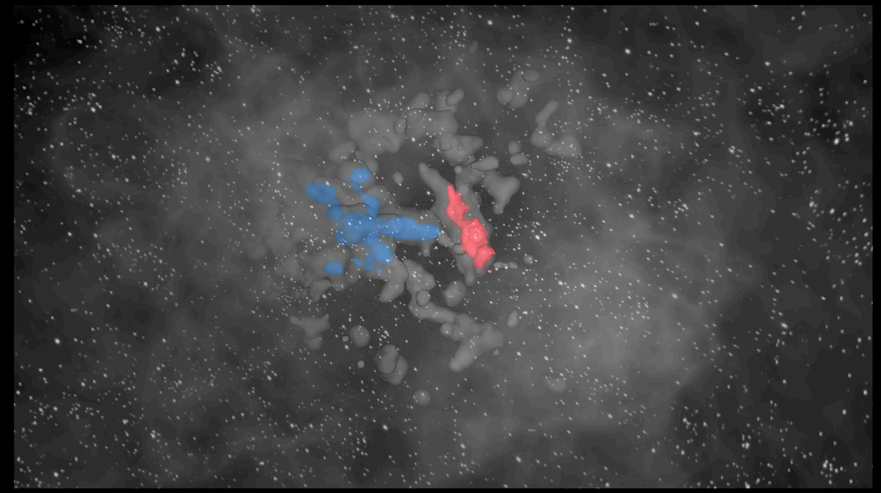
High Tea Menu





What was I doing today?





Ultimately, the text in this single document needs to be moved Templeton's form, but we consolidate it here to facilitate internal collaboration and review.

Sections marked with green character counts are "final"

1. Project Title (150 Character Limit including spaces and punctuation):

The Path-to Foundation: Appreciating Science through its History

2. Executive Summary (1,300 Character Limit including spaces and punctuation): * 1274

The Path-to Foundation will tell the stories behind great scientific achievements. Its founding was inspired by a poster and online website known as "The Path to Newton" (PtN).

This proposal addresses these **questions**.

1. Which aspects of the Path-to format (**posters, narratives, connections** between infographic and narrative, **Fairs**) facilitate the most:
   a. engagement;
   b. appreciation of the origins and processes of science;
   c. content understanding
2. How can we **customize formats** and **curricula** to **maximize** engagement, appreciation, and/or content understanding?
3. **How do results vary across audiences** (e.g. age, role, location, background)?

storyboard(s) for videos to accompany:

Zucker at al. 2021 (submitted to *ApJ*)

Bialy et al. 2021 (in press *ApJL*)

& Zucker et al. 2021 (in prep for *Nature*)

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

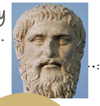
Motion needs a little push.

ANAXAGOROS
510–428 BCE
Greek

Motion must have a cause

SOCRATES
470–399 BCE
Greek

PLATO
427–347 BCE
Greek



Symmetry rules.

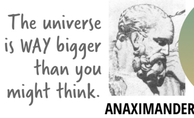
The air moves objects through it

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

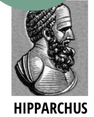
Earth is stationary center of the universe

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

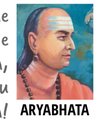
Celestial and terrestrial phenomena similar

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

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

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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.

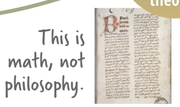
AL-TUSI
1201–1274
Persian

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?

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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

Aryabhatiya
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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

PREDICTIONX

SUN AT CENTER (⊕ BELIEVED EARTH AT CENTER)

GNOMON
ASTROLABE
PRINTING PRESS
TELESCOPE
ARITHMETIC
ZERO AS NUMERAL
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Polish

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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

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1295–1358
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Simple circular orbits work with better math

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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

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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

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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

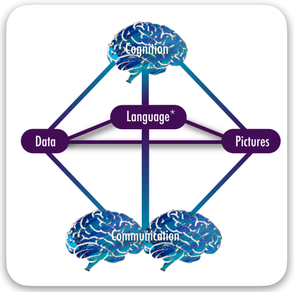
Synopsis Astronomia Cometicae
Edmond Halley
1705

THE PERSEUS-TAURUS SUPERSHELL IN SPACE

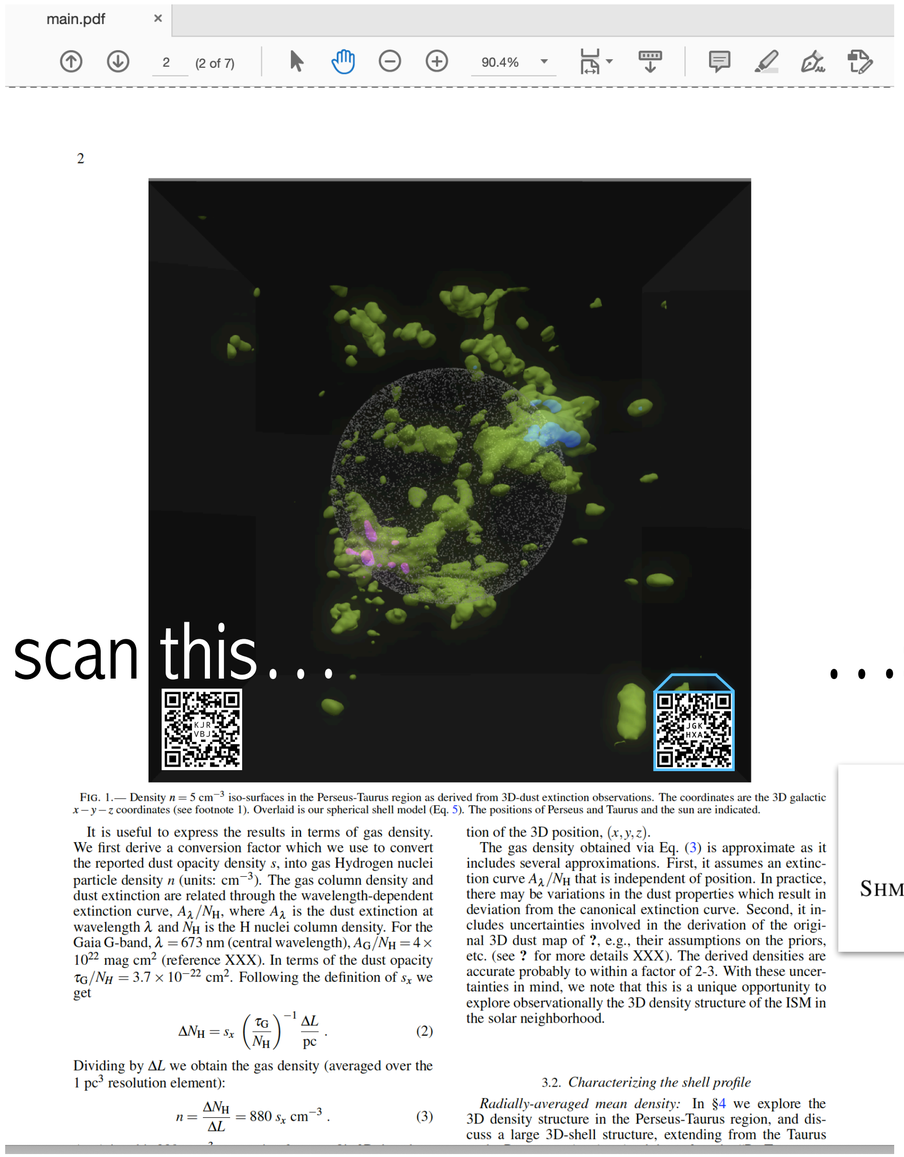
brought to you in 2021 by an international team of scientists from
Center for Astrophysics | Harvard & Smithsonian, Harvard Radcliffe Institute, University of Vienna, University of Wisconsin, Max-Planck Institute, Ludwig Maximillian University, and technology from ESA, NASA, NSF and Delightex.

animation by Jasen Lux Chambers

Publishing's interactive Cutting-Edge & (Augmented) Future



scan this…

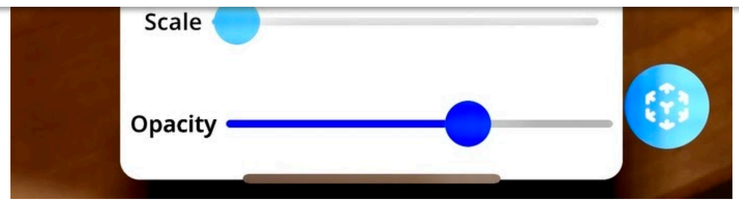


BIALY ET AL. 2021

…see this

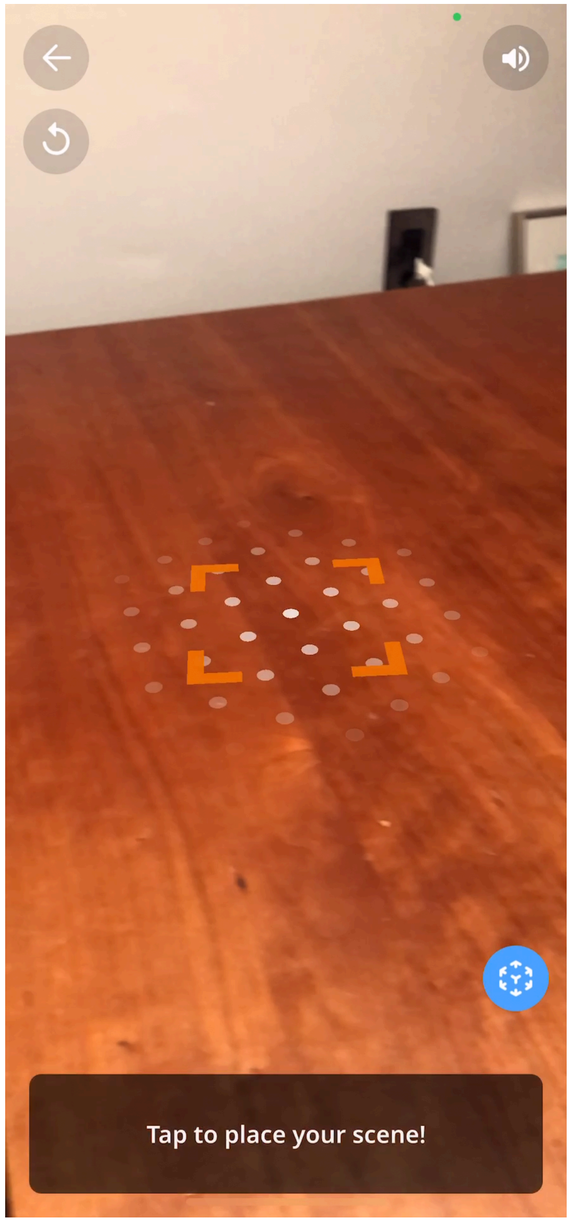
THE PER-TAU SHELL:
A GIANT STAR-FORMING SPHERICAL SHELL REVEALED BY 3D DUST OBSERVATIONS

SHMUEL BIALY[1]*, CATHERINE ZUCKER[1], ALYSSA GOODMAN[1,2], MICHAEL M. FOLEY[1], JOÃO ALVES[2,3], VADIM A. SEMENOV[1], ROBERT BENJAMIN[4], REIMAR LEIKE[5,6], TORSTEN ENßLIN[5,6]



Publishing's interactive Cutting-Edge & (Augmented) Future

KJR
VBJ



NSF

HARVARD UNIVERSITY

glue
multidimensional data exploration

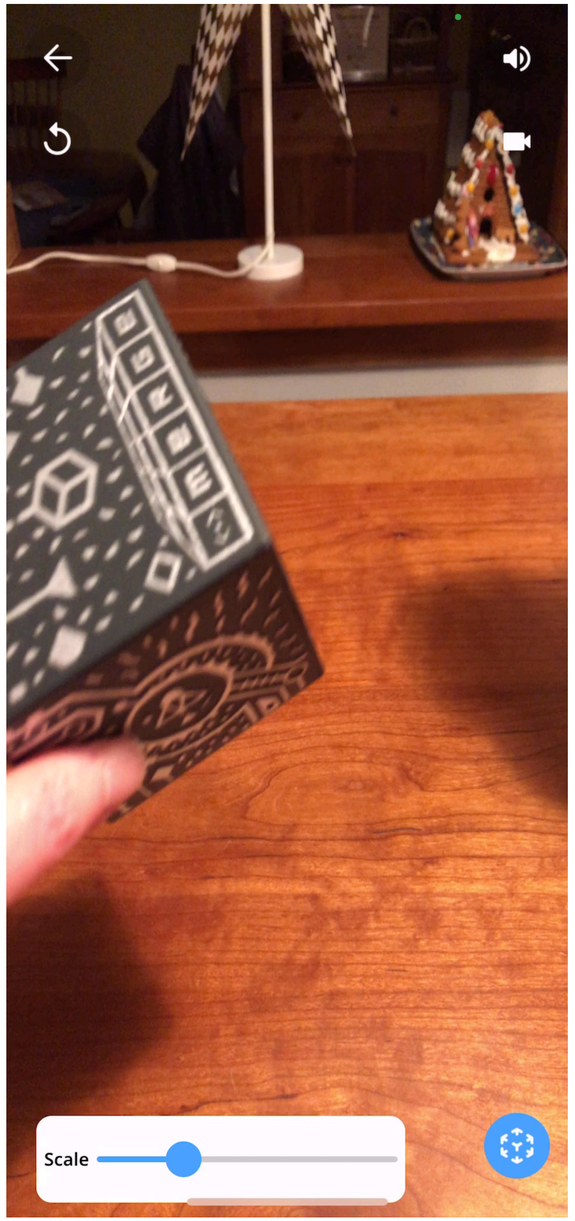
CO SPACES EDU

AMERICAN ASTRONOMICAL SOCIETY

JOHNS HOPKINS UNIVERSITY

STScI | SPACE TELESCOPE SCIENCE INSTITUTE

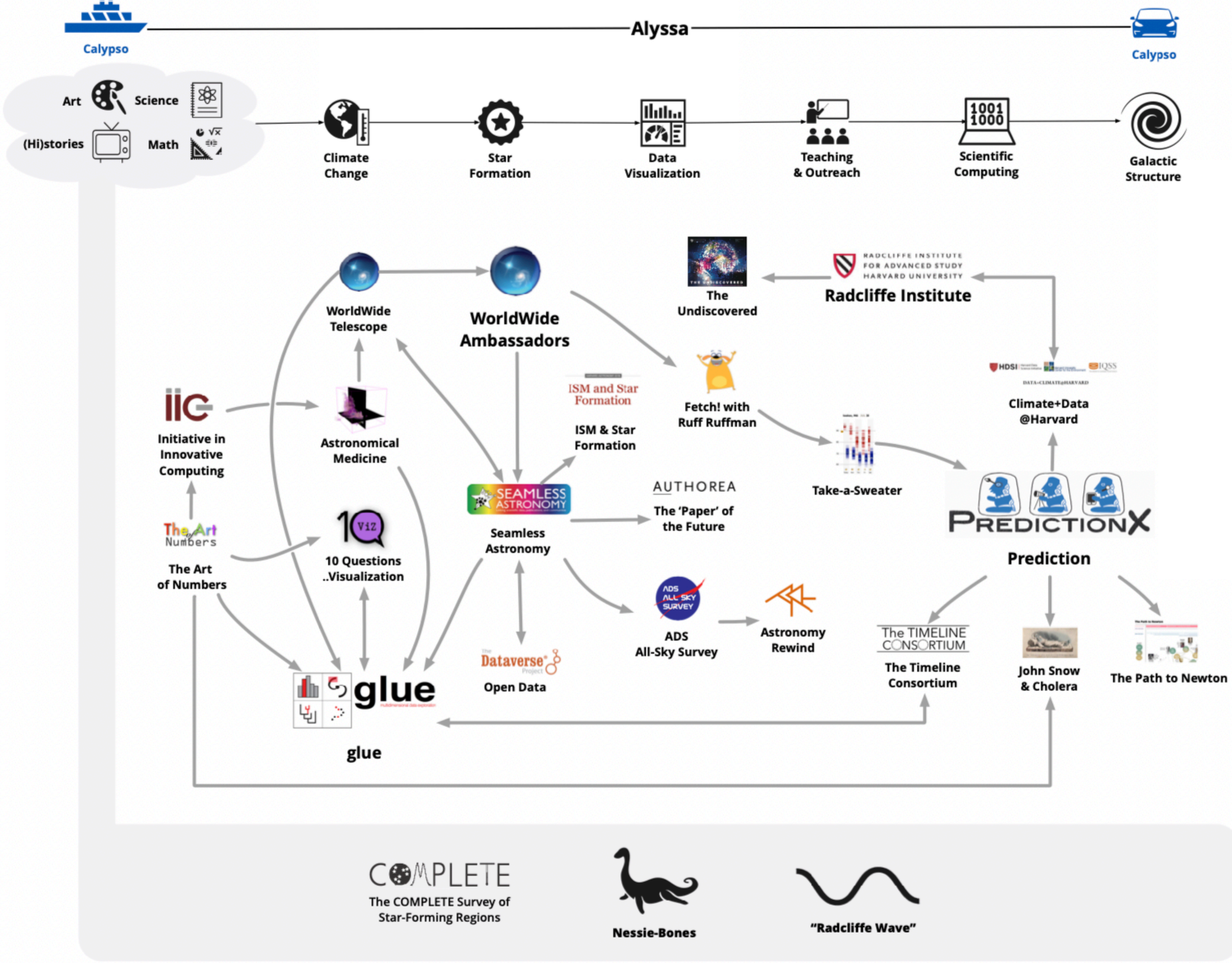
Northeastern University



JGK
HXA

DEMO DATA AND AR TECHNOLOGY WILL APPEAR IN BIALY ET AL. 2021

It really does
all fit together,
I promise.



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CENTER FOR ASTROPHYSICS
HARVARD & SMITHSONIAN

PRODUCER: ALYSSA GOODMAN
WRITER : NADIA WHITEHEAD
CONTRIBUTORS: CATHERINE ZUCKER, SHMUEL BIALY, MIKE FOLEY
ANIMATION: JASEN LUX CHAMBERS

MADE POSSIBLE BY… TECHNOLOGY FROM

glue
multidimensional data exploration

plotly

bokeh

AMERICAN ASTRONOMICAL SOCIETY
WORLDWIDE TELESCOPE

The Astropy Project

CO SPACES

esa

delightex

AND SUPPORT FROM

NASA

NSF

GORDON AND BETTY MOORE FOUNDATION

ITC
Institute for Theory and Computation

HDSI | Harvard Data Science Initiative

cnrs

AND COLLABORATORS AT

VE RI TAS HARVARD

STScI | SPACE TELESCOPE SCIENCE INSTITUTE

MAX-PLANCK-GESELLSCHAFT

universität wien

I2

AAS AMERICAN ASTRONOMICAL SOCIETY

University of Wisconsin Whitewater

Last week…

←Paris
for the
"Interstellar Institute"

Strasbourg →
for
Augmented Reality