What does Jacques Cousteau have to do with a self-driving car?

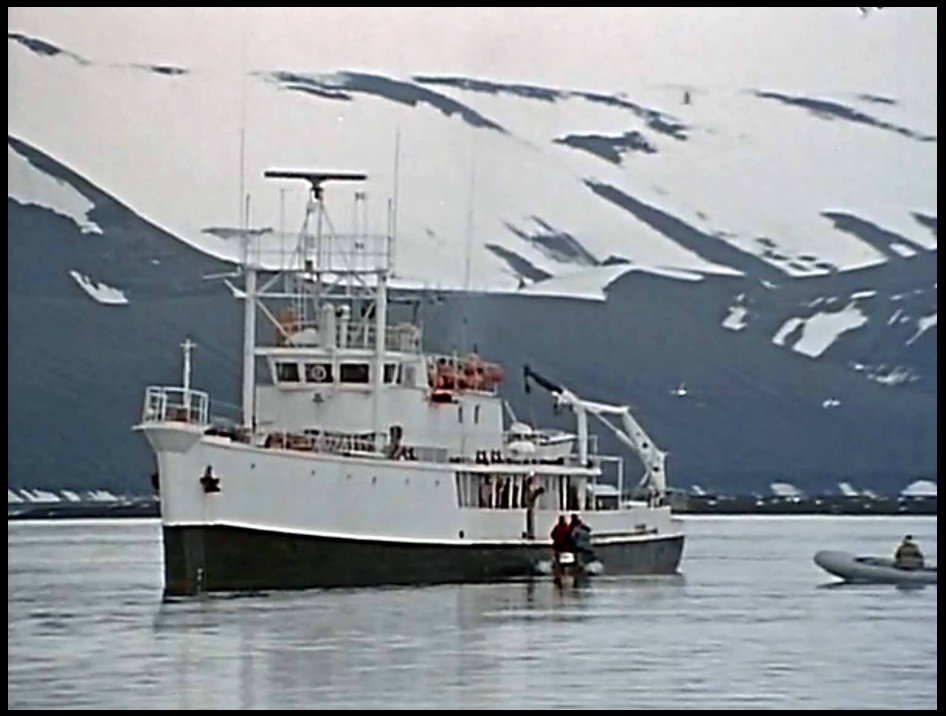
Calypso

Jacques Cousteau

Calypso

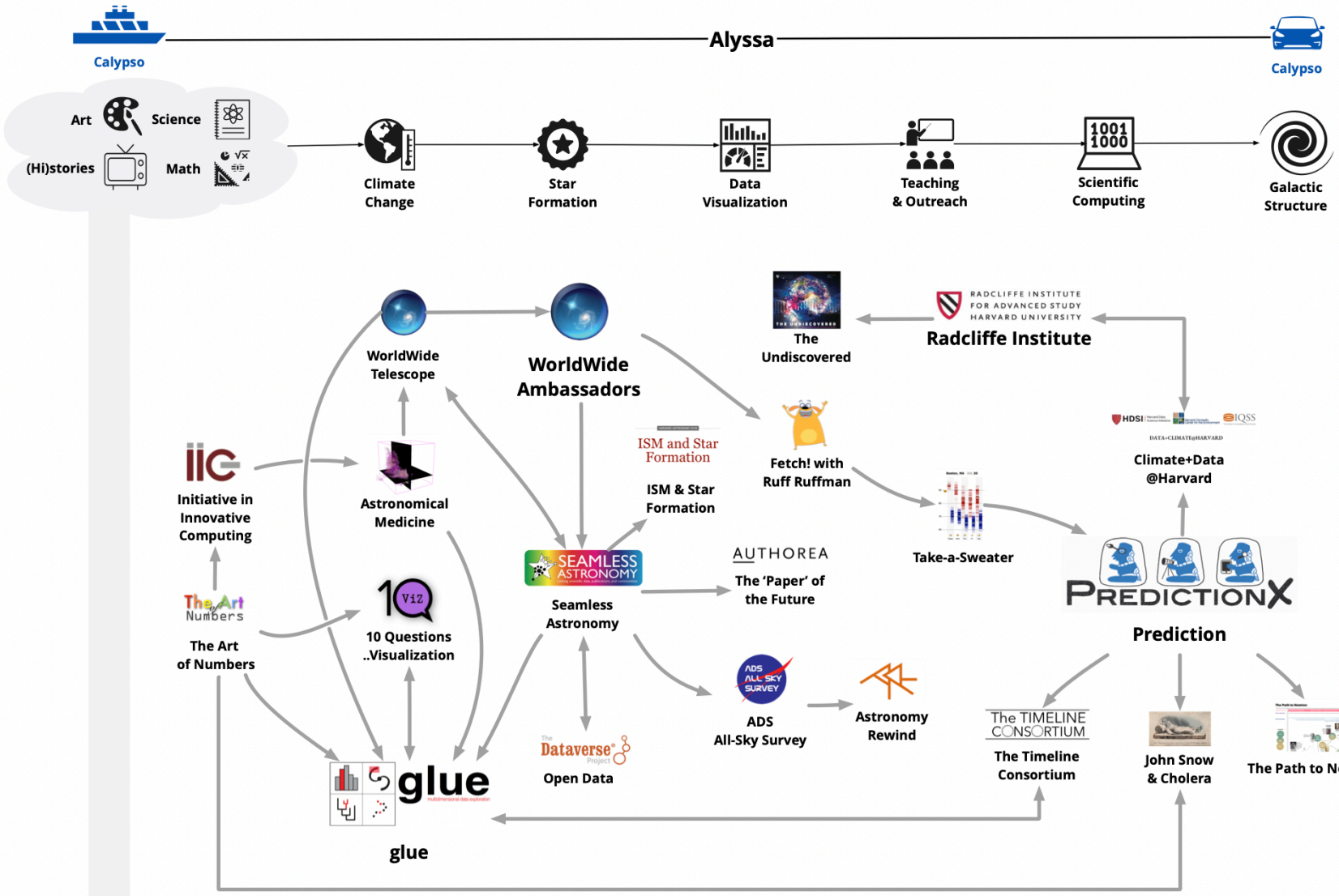
Elon Musk

Calypso to Calypso



Calypso to Calypso

Alyssa


Calypso
Alyssa
Calypso
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Science
(Hi)stories
Math
Climate Change
Star Formation
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Galactic Structure
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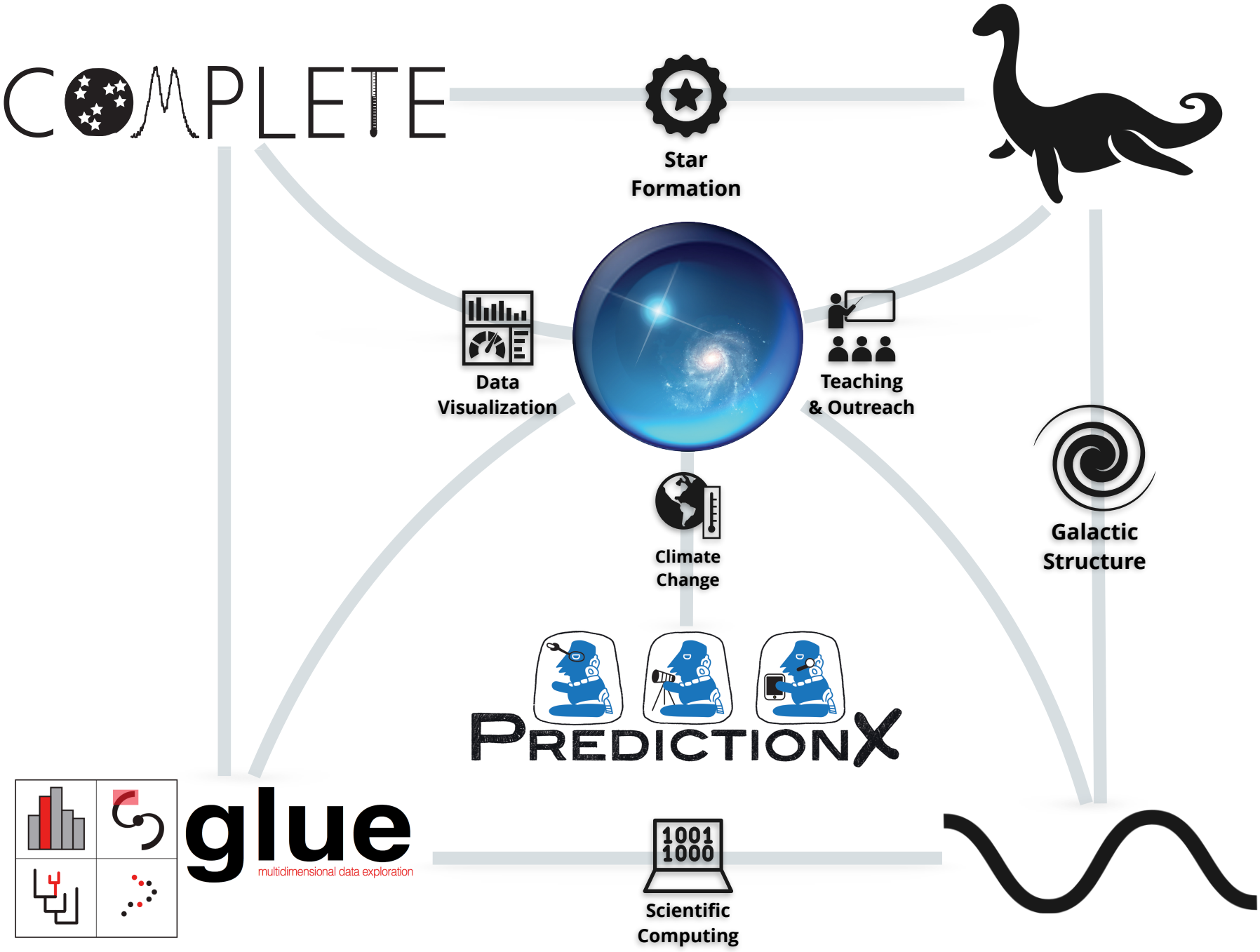
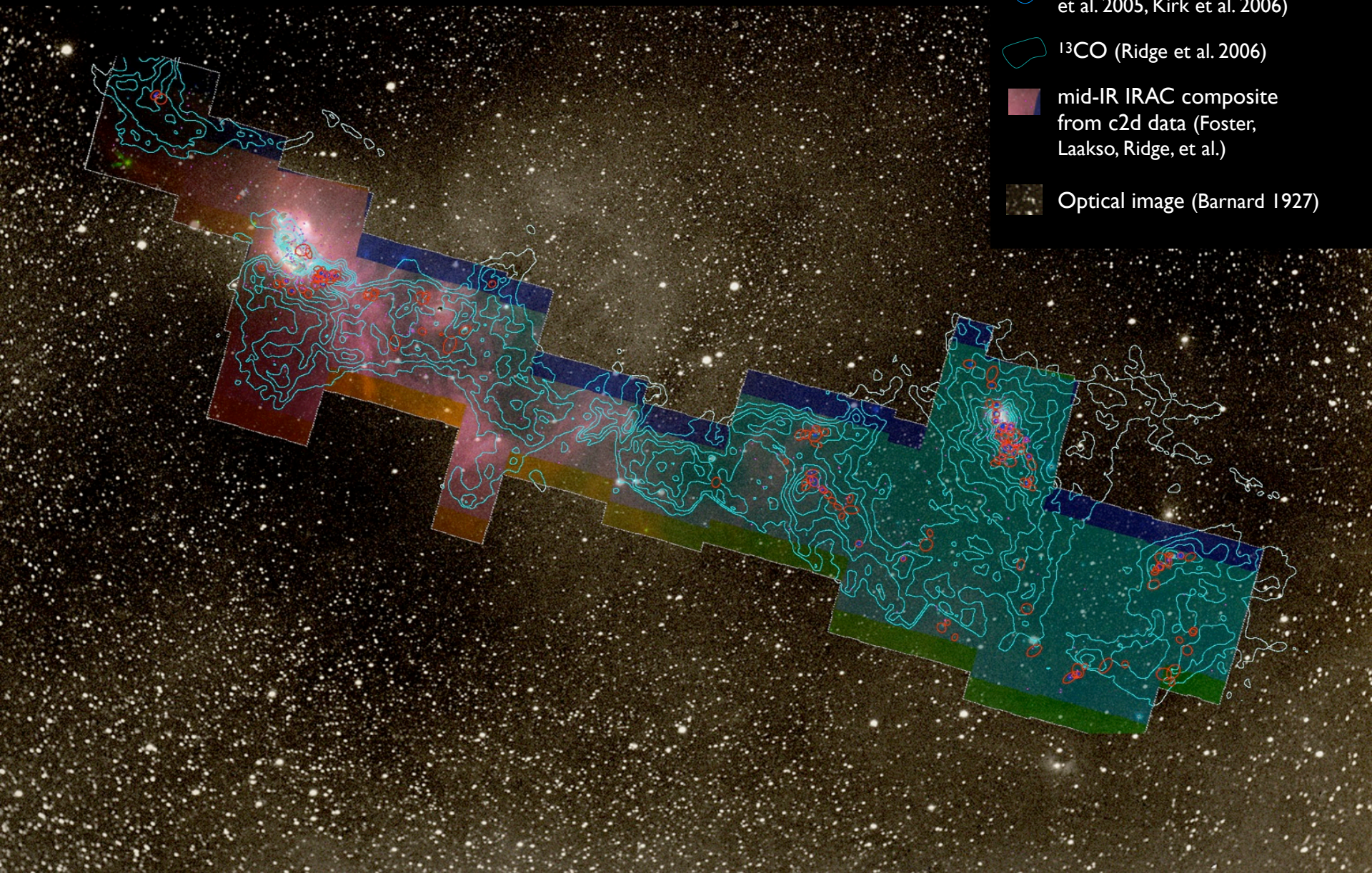
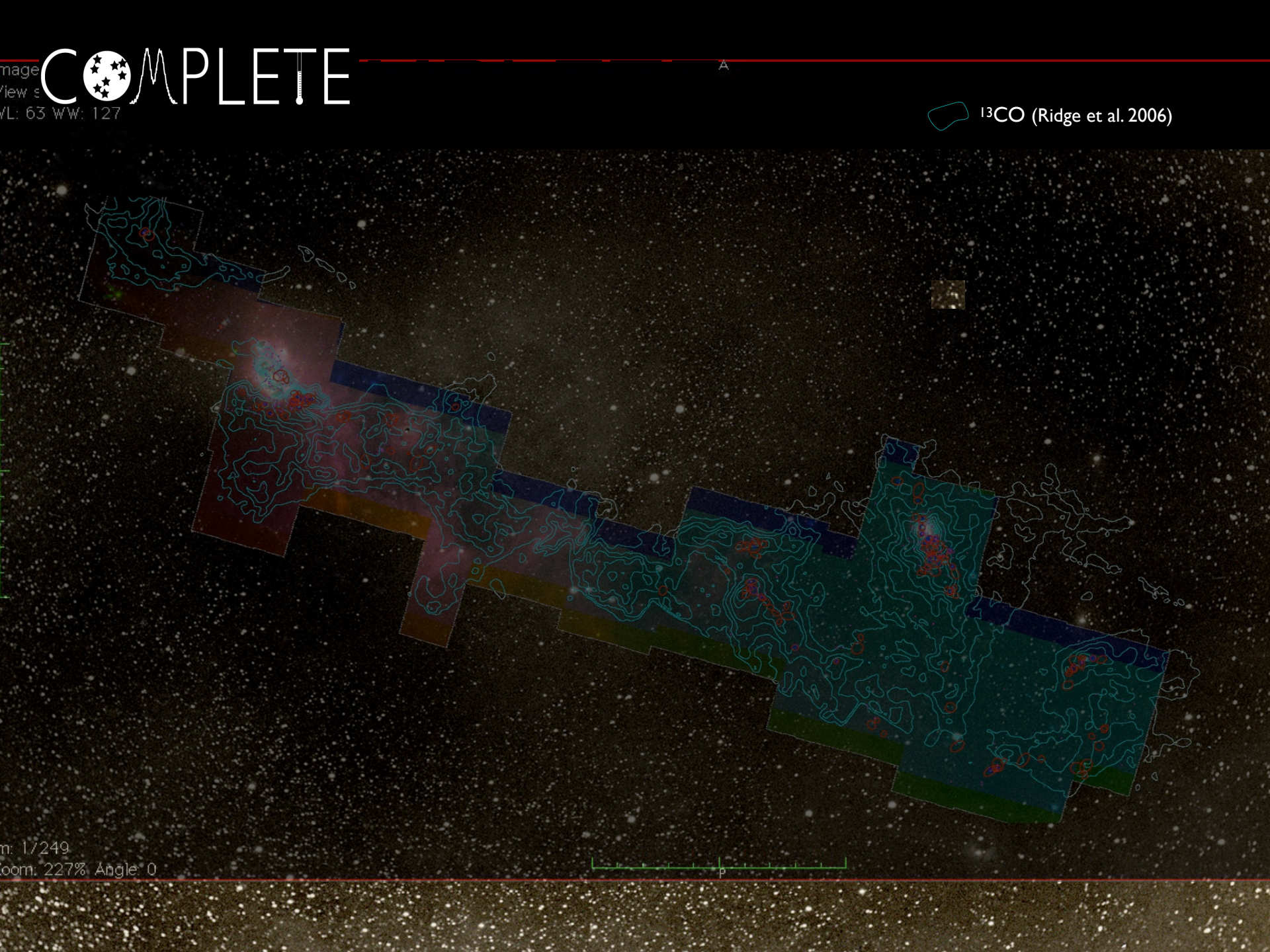

COMPLETE
Star Formation
Data Visualization
Teaching & Outreach
Climate Change
Galactic Structure
PREDICTIONX
glue
multidimensional data exploration
1001
1000
Scientific Computing

COMPLETE

The **CO**ordinated **M**olecular **P**robe **L**ine **E**xtinction **T**hermal **E**mission Survey of Star-Forming Regions 2002-12

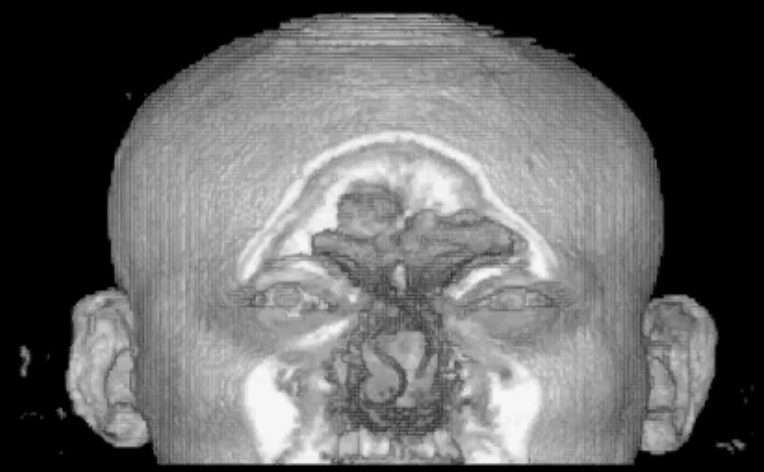
COMPLETE


mm peak (Enoch et al. 2006)
sub-mm peak (Hatchell et al. 2005, Kirk et al. 2006)
^{13}CO (Ridge et al. 2006)
mid-IR IRAC composite from c2d data (Foster, Laakso, Ridge, et al.)
Optical image (Barnard 1927)

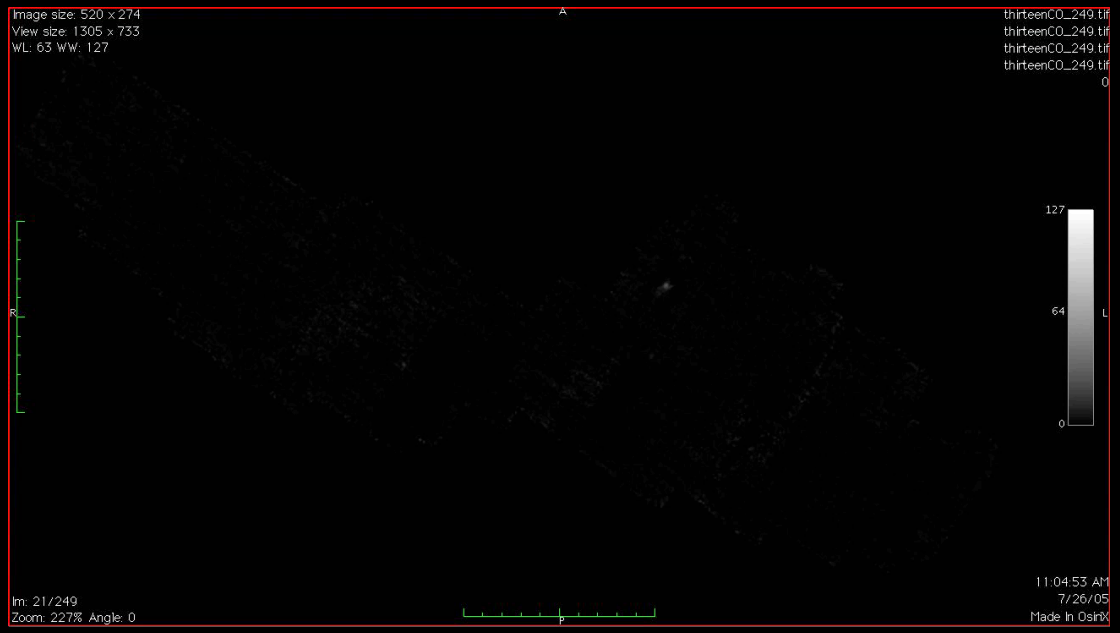

COMPLETE
^{13}CO (Ridge et al. 2006)

Astronomical Medicine

"KEITH"



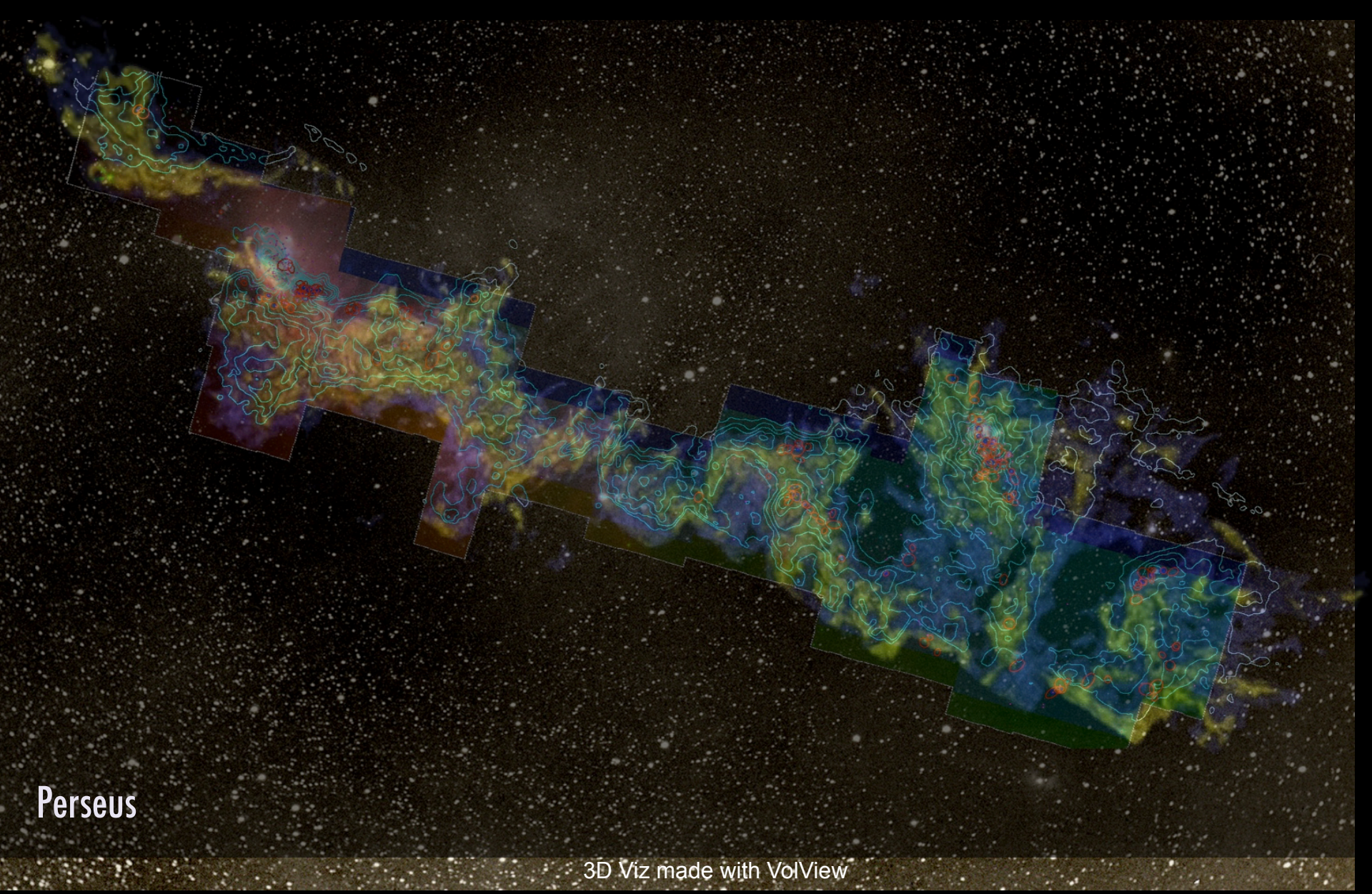
"PERSEUS"



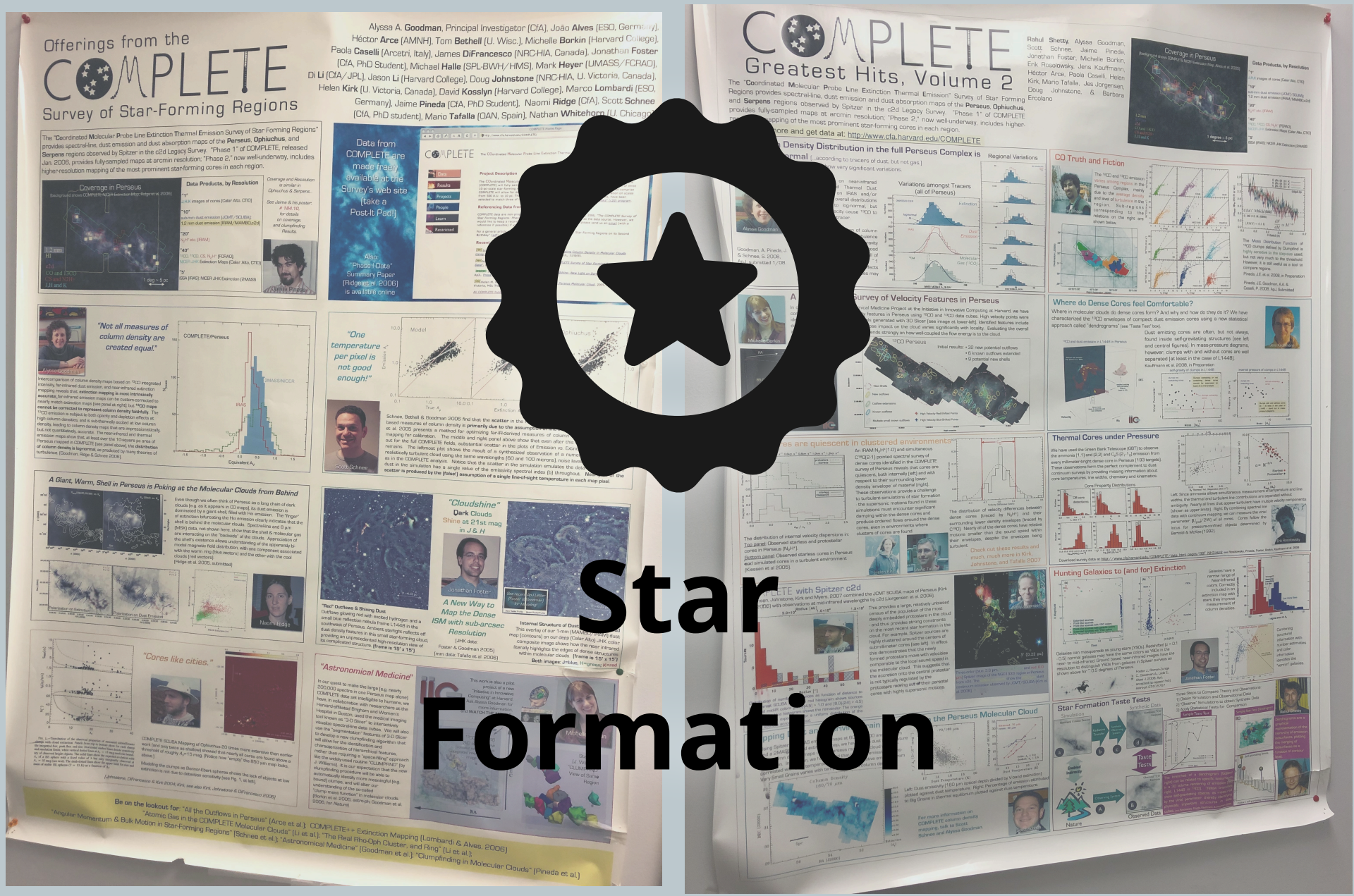
"z" is depth into head

"z" is line-of-sight velocity

"AstroMed" collaborators include Douglas Alan, Chris Beaumont, Michelle Borkin, Jonathan Foster, Michael Halle, Nick Holliman, Jens Kauffmann, Jaime Pineda, Tudor Platon, Erik Rosolowsky, and more



AstronomicalMedicine@ iic COMPLETE


Offerings from the
COMPLETE
Survey of Star-Forming Regions
Alyssa A. Goodman, Principal Investigator (CfA), João Alves (ESO, Germany), Héctor Arce (AMNH), Tom Bethell (U. Wisc.), Michelle Borkin (Harvard College), Paola Caselli (Arcetri, Italy), James DiFrancesco (NRC-HIA, Canada), Jonathan Foster (CfA, PhD Student), Michael Halle (SPL-BWH/HMS), Mark Heyer (UMASS/FCRAO), Di Li (CfA/JPL), Jason Li (Harvard College), Doug Johnstone (NRC-HIA, U. Victoria, Canada), Helen Kirk (U. Victoria, Canada), David Kosslyn (Harvard College), Marco Lombardi (ESO, Germany), Jaime Pineda (CfA, PhD Student), Naomi Ridge (CfA), Scott Schnee (CfA, PhD student), Mario Tafalla (OAN, Spain), Nathan Whitehorn (U. Chicago)
The "Coordinated Molecular Probe Line Extinction Thermal Emission Survey of Star Forming Regions" provides spectral-line, dust emission and dust absorption maps of the Perseus, Ophiuchus, and Serpens regions observed by Spitzer in the c2d Legacy Survey. "Phase 1" of COMPLETE, released Jan. 2006, provides fully-sampled maps at arcmin resolution; "Phase 2," now well-underway, includes higher-resolution mapping of the most prominent star-forming cores in each region.
Coverage in Perseus
Data Products, by Resolution
Coverage and Resolution is similar in Ophiuchus & Serpens.
See Jaime & his poster # 184.10, for details on coverage, and clumpfinding Results.
Data from COMPLETE are made freely available at the Survey's web site (take a Post-It Pad!)
Also: "Phase 1 Data" Summary Paper (Ridge et al. 2006) is available online
"Not all measures of column density are created equal."
Alyssa Goodman
COMPLETE/Perseus
Equivalent A_V
"One temperature per pixel is not good enough!"
Scott Schnee
Schnee, Bethell & Goodman 2006 find that the scatter in these...
A Giant, Warm, Shell in Perseus is Poking at the Molecular Clouds from Behind
Even though we often think of Perseus as a long chain of dark clouds (e.g. as it appears in CO maps), its dust emission is dominated by a giant shell, filled with Hα emission. The "fringe" of extinction bifurcating the Hα emission clearly indicates that the shell is behind the molecular clouds. Spectraline and 8 μm (MSX) data, not shown here, show that the shell & molecular gas are interacting on the "backside" of the clouds. Appreciation of the shell's existence allows understanding of the apparently bi-modal magnetic field distribution, with one component associated with the warm ring (blue vectors) and the other with the cool clouds (red vectors).
(Ridge et al. 2005, submitted)
Naomi Ridge
"Cloudshine"
Dark Clouds Shine at 21st mag in J & H
Jonathan Foster
A New Way to Map the Dense ISM with sub-arcsec Resolution
"Red" Outflows & Shining Dust
Internal Structure of Dust
"Cores like cities."
"Astronomical Medicine"
Be on the lookout for: "All the Outflows in Perseus" (Arce et al.); COMPLETE++ Extinction Mapping (Lombardi & Alves, 2006)
"Atomic Gas in the COMPLETE Molecular Clouds" (Li et al.); "The Real Rho-Oph Cluster, and Ring" (Li et al.)
"Angular Momentum & Bulk Motion in Star-Forming Regions" (Schnee et al.); "Astronomical Medicine" (Goodman et al.); "Clumpfinding in Molecular Clouds" (Pineda et al.)
COMPLETE
Greatest Hits, Volume 2
Rahul Shetty, Alyssa Goodman, Scott Schnee, Jaime Pineda, Jonathan Foster, Michelle Borkin, Erik Rosolowsky, Jens Kauffmann, Héctor Arce, Paola Caselli, Helen Kirk, Mario Tafalla, Jes Jorgensen, Doug Johnstone, & Barbara Ercolano
Coverage in Perseus
Data Products, by Resolution
Density Distribution in the full Perseus Complex is
Regional Variations
Variations amongst Tracers (all of Perseus)
CO Truth and Fiction
Where do Dense Cores feel Comfortable?
Survey of Velocity Features in Perseus
Thermal Cores under Pressure
Hunting Galaxies to (and for) Extinction
Star Formation Taste Tests
Star Formation

COMPLETE (in) "WorldWide Telescope"

The Dataverse® Project

Open Data

Data Visualization

COMPLETE Data Available

Center on Perseus | Center on Ophichus | Center on Serpens

Full-Cloud Data (Phase I, All Data Available)

	Show	Perseus	Ophiuchus	Serpens	Link
T: HI Data Cube	☑	√	√	∅	Data
IRAS: Av/Temp Maps	☑	√	√	√	Data
FCRAO: 12CO	☑	√	√	√	Data
FCRAO: 13CO		√	√	√	Data
JCMT: 850 microns	☑	√	√	∅	Data
Spitzer c2d: IRAC 1,3 (3.6,5.8 µm)	☑	√	√	√	Data
Spitzer c2d: IRAC 2,4 (4.5,8 µm)	☑	√	√	√	Data
CSO/Bolocam: 1.2-mm	☑	√	∅	∅	Data
Spitzer MIPS: Derived Dust Map	☑	√	∅	∅	Data

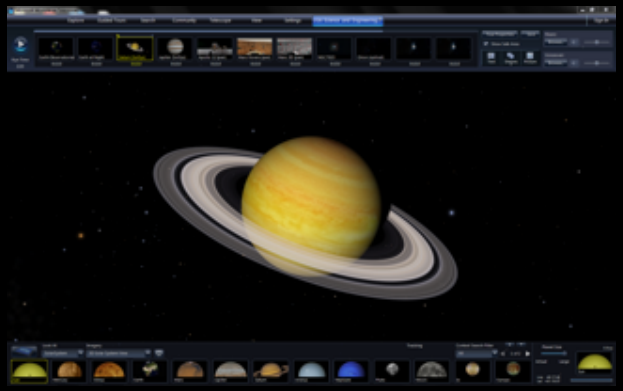
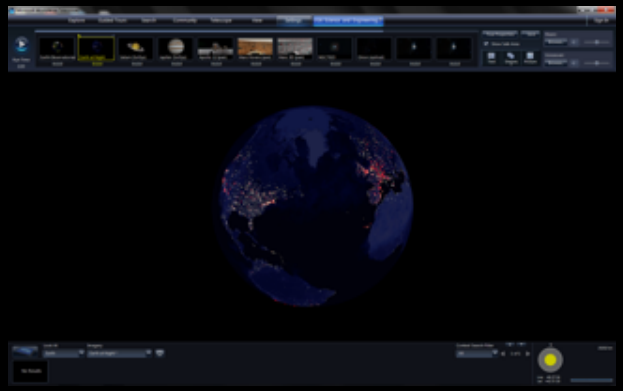
Targeted Regions (Phase II, Some Data Not Yet Available)

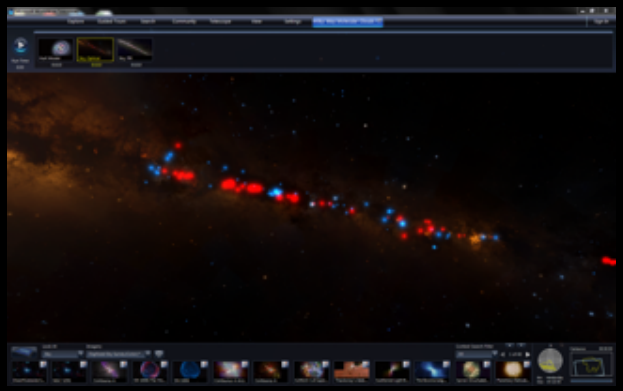
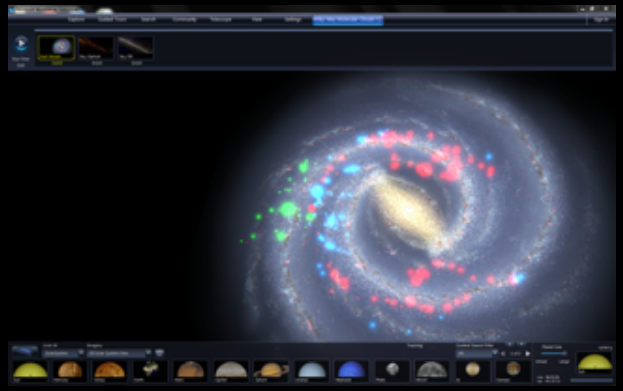
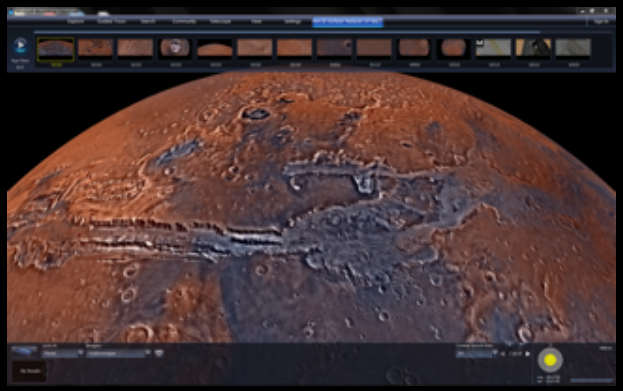
CTIO/Calar Alto: NIR (J,H,Ks)	☑	√	√	∅	Data
IRAM 30-m: N2H+ and C18O	☑	√	∅	∅	Data
IRAM 30-m: 1.1-mm continuum	☑	√	∅	∅	Data
Megacam/MMT: r,i,z images	☑	√	∅	∅	Data

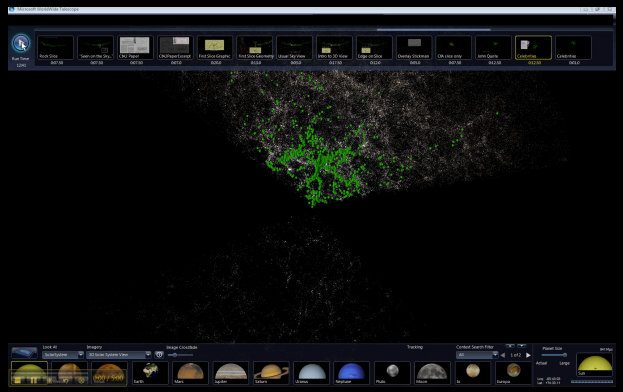
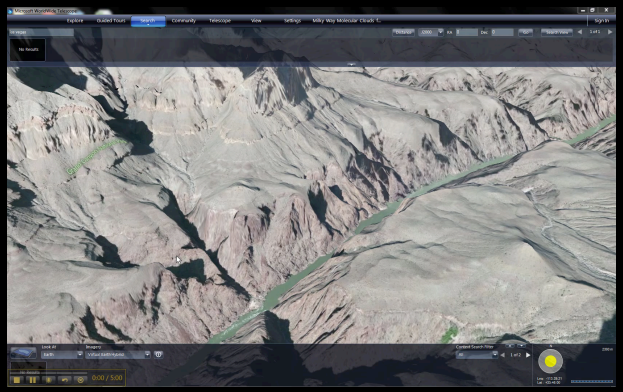
Catalogs & Pointed Surveys

NH3 Pointed Survey	☑	√	∅	∅	Data
YSO Candidate list (c2d)	☐	√	√	√	Data

WorldWide Telescope" 2007-

Experience WorldWide Telescope, free, at **worldwidetelescope.org**

[demo]

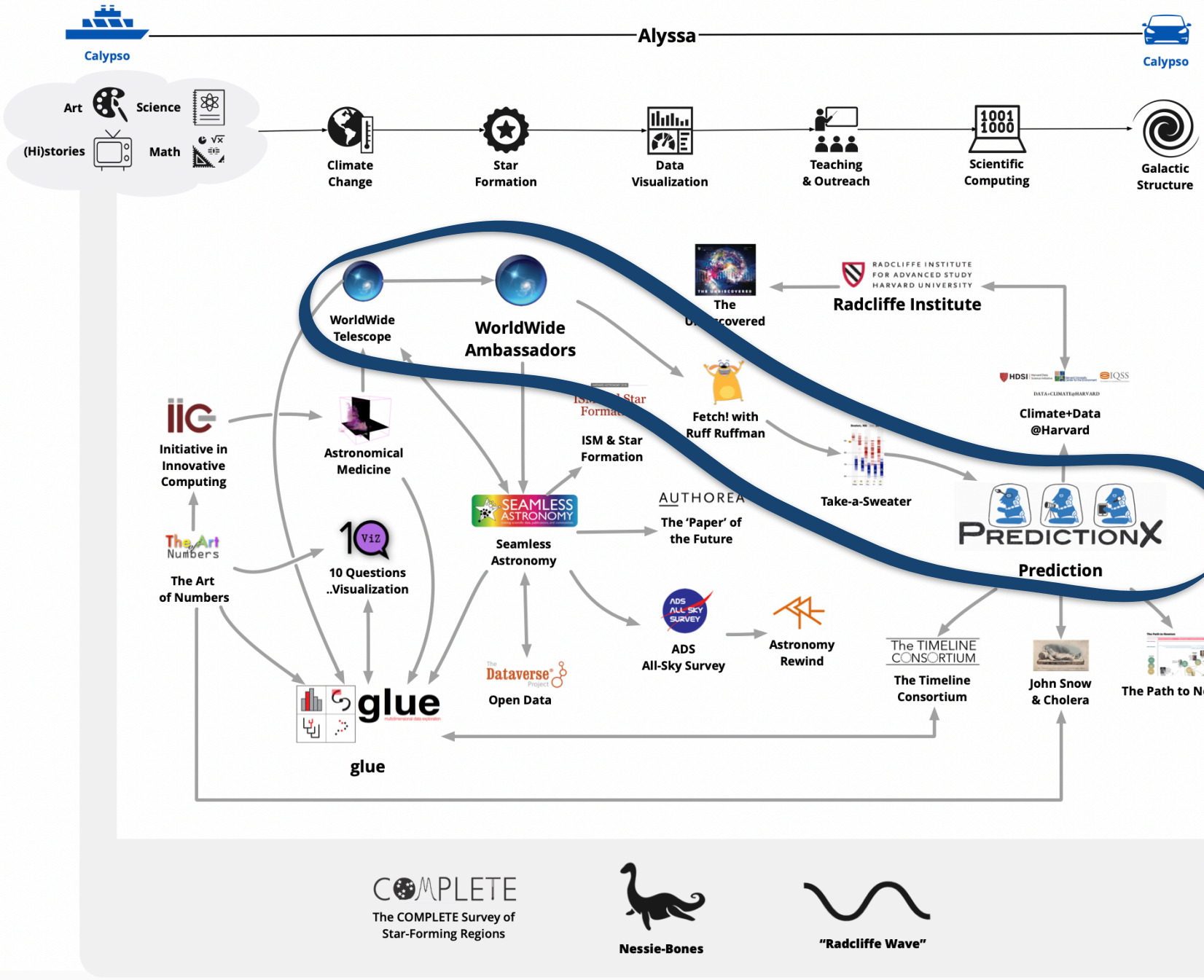
Teaching
& Outreach

Climate
Change

PREDICTIONX

1001
1000

Scientific
Computing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glue
glue
COMPLETE
The COMPLETE Survey of Star-Forming Regions
Nessie-Bones
"Radcliffe Wave"

Teaching
& Outreach

Climate
Change

PREDICTIONX ~2014-

1001
1000

Scientific
Computing

PredictionX

PredictionX: The Past & Present of the Future

Essentials

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

Omens, Oracles & Prophecies

- *Mesopotamian Haruspicy*
- *Egyptian Priests*
- *Yoruba Ifa*
- *Tarot*
- *Roman Augury*
- **The Diviner's Guide**
- *Casting Lots*
- *Chinese Oracle Bones*
- *Greek Astronomy*
- *Oracle of Delphi*
- *Turkish Tasseography*
- *Astrology*
- *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**
- ▶ *Indian Mathematics*
- *European Renaissance*
- ▶ *The Royal Society*

John Snow & Cholera
- *Cholera Map*

Lost without Longitude (Navigation)
- *Help, I'm Lost!*
- *Tools of the Navigator*

Modern Simulation

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

Wealth
- ▶ *Personal Finance*
- ▶ *(Global) Economics*

The Future of the Future
- ▶ *Artificial Intelligence*
- *Derek's Day*

Earth
- ▶ *Climate Change*
- ▶ *Tent Tarot*
- ▶ *Earthquakes*

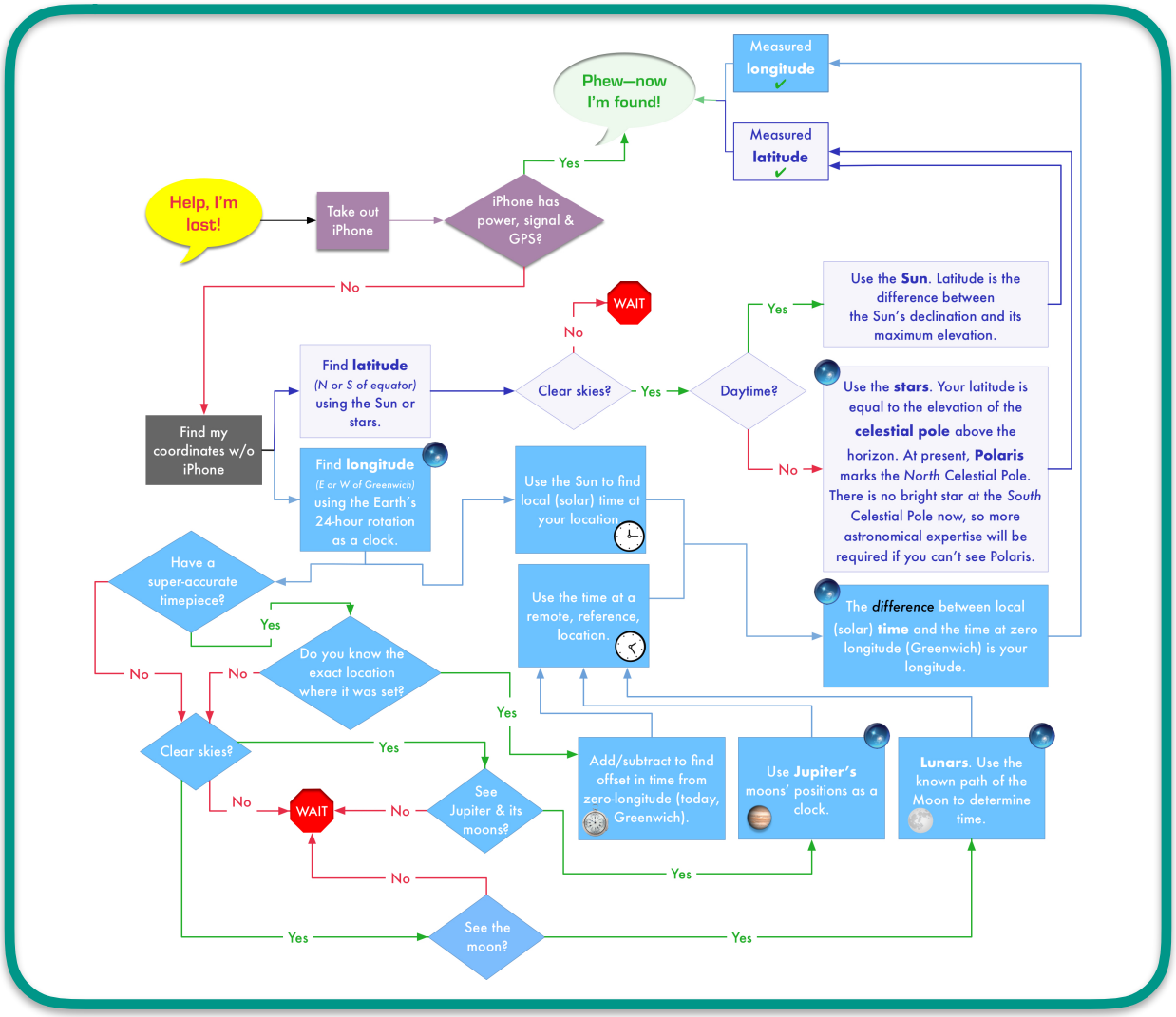
Space
- *Futures of our Universe*

Finished | Coming Soon | Planned | Interactive Resource | ▶ video(s) | edX link to edX (often contains videos + interactives, not marked separately here)

HarvardX · edX · predictionx.org

with many thanks to HarvardX course producer Drew Lichtenstein, research assistant Jais Brohinsky, designer Katie Peek+ dozens of other experts at Harvard and beyond

“Lost without Longitude”



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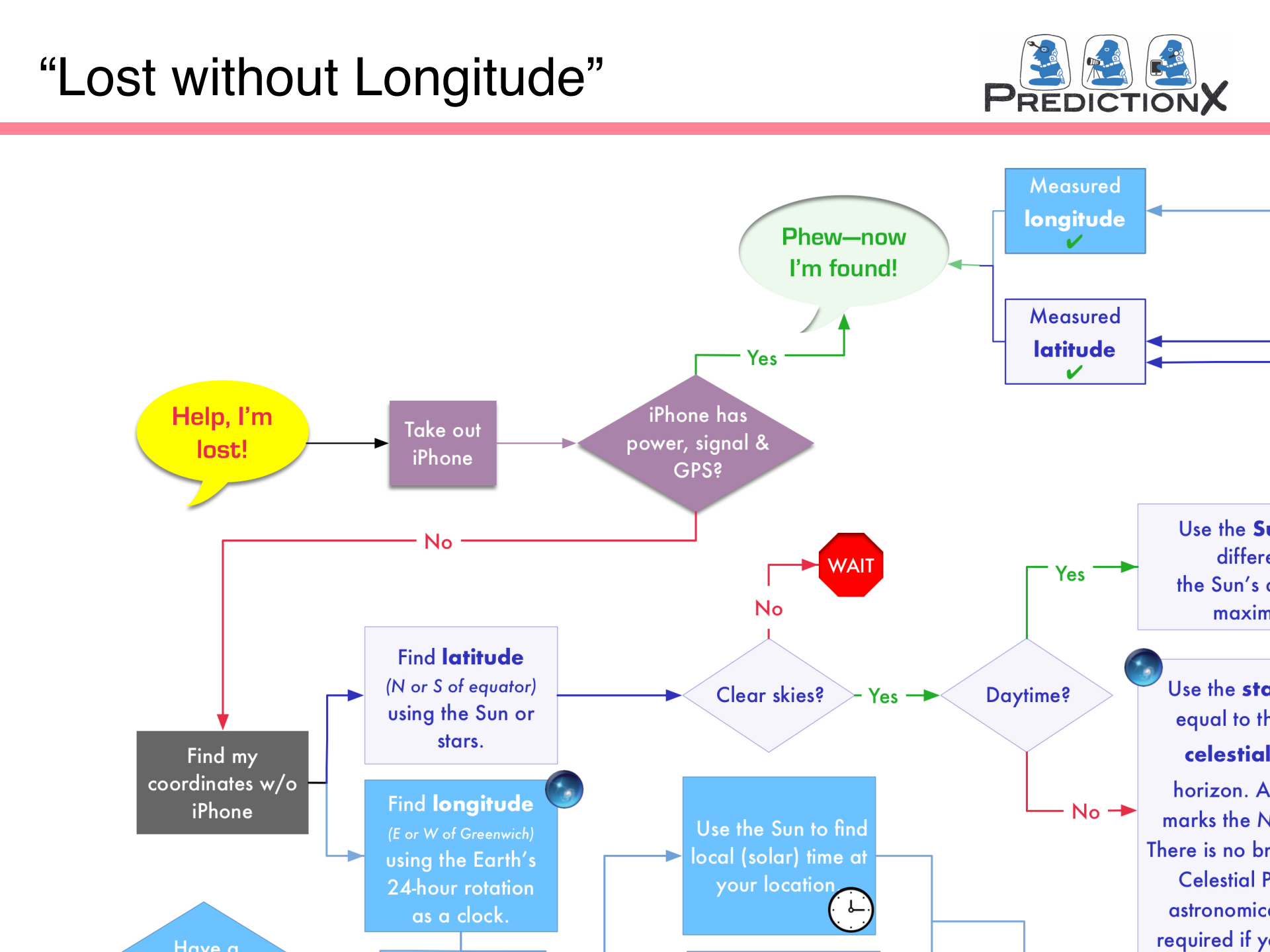

Earth as a Clock

The Celestial Sphere

Jupiter's Moons

Latitude & Longitude

Lunars on the Sky

Why Lunars are Hard

PredictionX

PredictionX: The Past & Present of the Future

Essentials

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edX

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edX

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edX

John Snow & Cholera

- *Cholera Map*

Modern Simulation

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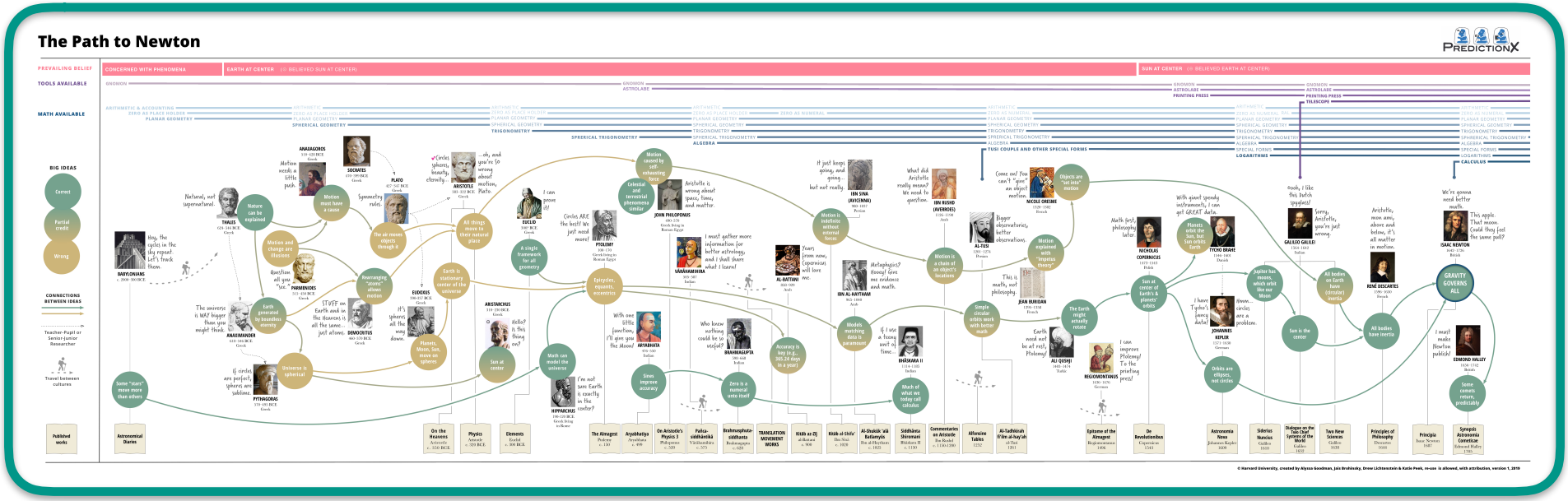
The Path to Newton

Alyssa Goodman,
Jais Brohinsky,
Drew Lichtenstein
& Katie Peek
on behalf of Harvard University



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The Path to Newton

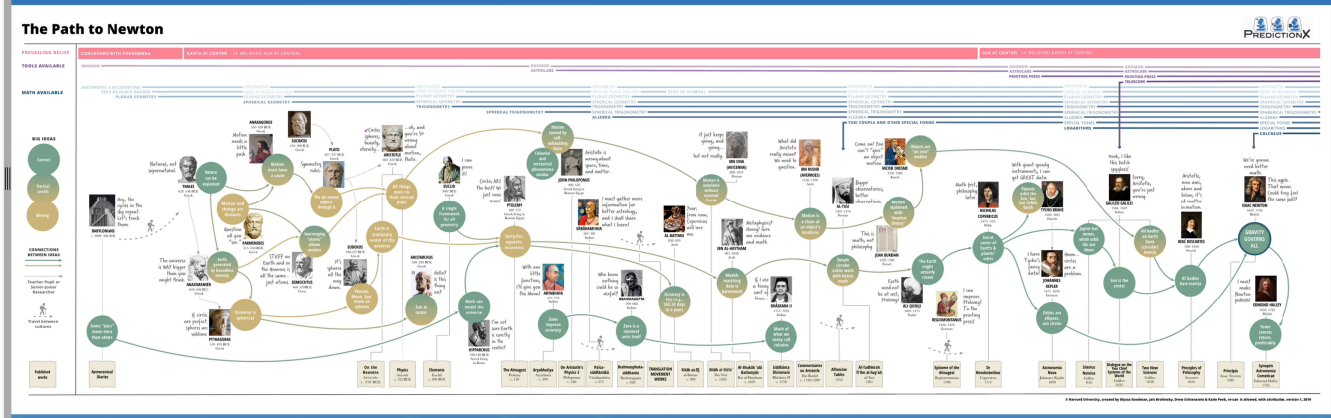
The Path to Newton

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 millennia, the ideas that led to Newton's built on earlier ideas through critique, amendment, and refutation. Newton's theory of gravity was not quite like the other ideas that drove our understanding of how the Universe moves forward, though--it was a monumental paradigm shift, from a world described by empirical rules, like those Kepler had discovered, to a world that could be predicted a priori--with no prior data about a system.

The Path to Newton is an attempt to demonstrate (some) of history behind how Newton knew what he knew and thought what he thought about motion. For many centuries, motion of objects in the Heavens (what we now think of as celestial mechanics) was considered categorically distinct from motion of objects on Earth (what was known as kinematics and, later, dynamics), so the Path focuses on philosophical and mathematical conceptions of the Universe and of how and why objects move on Earth, in order to explain how an ultimately unified theory of motion came to be.

Steps along the Path were facilitated by material technologies and greatly affected by religious doctrine, cultural exchange, and the migration and translation of ideas. The Path highlights the cultures, thinkers and tinkerers who wrestled ideas about motion into the stories, cosmologies, mathematics, tools, and data that lay before Newton as he worked. Each person highlighted along the Path stands in for a constellation of factors, often groups of people, that led to the historical recording or transmission of key ideas. While The Path employs these contributors as representatives and access points to seminal ideas and innovations necessary for a predictive theory of gravity, the immensity of the



pathto-x.github.io — javascript by Francisco Ortiz

The Path to Newton

PREVAILING BELIEF

TOOLS AVAILABLE

MATH AVAILABLE

CONCERNED WITH PHENOMENA

EARTH AT CENTER (☉ BELIEVED SUN AT CENTER)

GNOMON

GNOMON
ASTRO

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

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

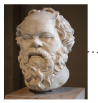
Question all you "see."

PARMENIDES
515–450 BCE
Greek

Motion needs a little push.

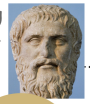
ANAXAGOROS
510–428 BCE
Greek

Motion must have a cause



SOCRATES
470–399 BCE
Greek

PLATO
427–347 BCE
Greek



Symmetry rules.

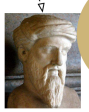
The air moves objects through it

The universe is WAY bigger than you might think.

ANAXIMANDER
610–546 BCE
Greek

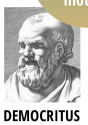
Earth generated by boundless eternity

Universe is spherical



If circles are perfect, spheres are sublime.

PYTHAGORAS
570–495 BCE
Greek



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

DEMOCRITUS
460–370 BCE
Greek

Rearranging "atoms" allows motion

It's spheres all the way down.

EUDOXUS
390-337 BCE
Greek

Planets, Moon, Sun, move on spheres

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

Sun at center

ARISTARCHUS
310–230 BCE
Greek

Hello? Is this thing on?

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

Circles ARE the best! We just need more!

PTOLEMY
100–170
Greek living in Roman Egypt

Epicycles, equants, eccentrics

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

On the Heavens
Aristotle
c. 350 BCE

Physics
Aristotle
c. 320 BCE

Elements
Euclid
c. 300 BCE

The Almagest
Ptolemy
c. 150

Aryab
Aryab
c. 4

Published works

SUN AT CENT

GNOMON
ASTROLABE

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

ZERO AS NUMERAL

ARITHMETIC
ZERO AS NUMERAL
PLANAR GEOMETRY
SPHERICAL GEOMETRY
TRIGONOMETRY
SPRERICAL TRIGONOMETRY
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

Who knew nothing could be so useful?

BRAHMAGUPTA
598–668
Indian

Sines improve accuracy

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

Zero is a numeral unto itself

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

PARCHUS
-120 BCE
eek living
Rome

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

IBN SINA (AVICENNA)
980–1037
Persian

Years from now, Copernicus will love me.

AL-BATTANI
858–929
Arab

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.

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

Motion explained with "impetus theory"

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

Math first, philosophy later.

NICHOLAS COPERNICUS
1473–1543
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

PREDICTIONX

SUN AT CENTER (⊕ BELIEVED EARTH AT CENTER)

GNOMON
ASTROLABE
PRINTING PRESS
ARITHMETIC
ZERO AS NUMERAL
PLANAR GEOMETRY
SPHERICAL GEOMETRY
TRIGONOMETRY
SPRERICAL TRIGONOMETRY
ALGEBRA
TUSI COUPLE AND OTHER SPECIAL FORMS

GNOMON
ASTROLABE
PRINTING PRESS
TELESCOPE
ARITHMETIC
ZERO AS NUMERAL
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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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Math first, philosophy later.

Sun at center of Earth's & planets' orbits

De Revolutionibus
Copernicus
1543

TYCHO BRAHE
1546–1601
Danish

With giant spendy instruments, I can get GREAT data.

Planets orbit the Sun, but Sun orbits Earth

JOHANNES KEPLER
1571–1630
German

I have Tycho's fancy data!

Hmm... circles are a problem.

Orbits are ellipses, not circles

Astronomia Nova
Johannes Kepler
1609

Jupiter has moons, which orbit like our Moon

Siderius Nuncius
Galileo
1610

Sun is the center

GALILEO GALILEI
1564–1642
Italian

Oooh, I like this Dutch spyglass!

Sorry, Aristotle, you're just wrong.

Dialogue on the Two Chief Systems of the World
Galileo
1632

All bodies on Earth have (circular) inertia

Two New Sciences
Galileo
1638

RENÉ DESCARTES
1596–1650
French

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

All bodies have inertia

Principles of Philosophy
Descartes
1644

ISAAC NEWTON
1642–1726
British

We're gonna need better math.

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

GRAVITY GOVERNS ALL

Principia
Isaac Newton
1687

EDMOND HALLEY
1656–1742
British

I must make Newton publish!

Some comets return, predictably

Synopsis Astronomia Cometicae
Edmond Halley
1705

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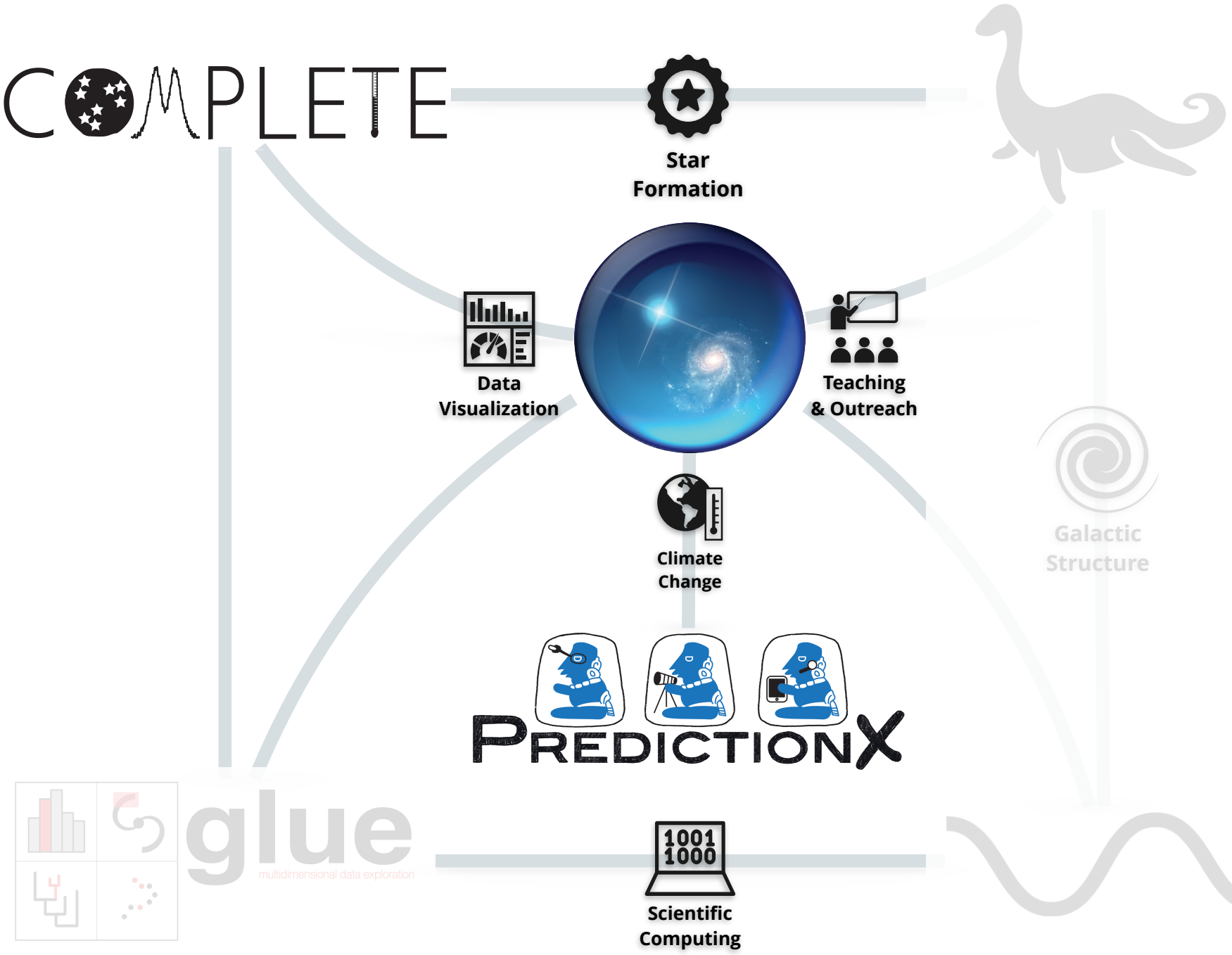

COMPLETE
Star Formation
Data Visualization
Teaching & Outreach
Climate Change
Galactic Structure
PREDICTIONX
glue
multidimensional data exploration
1001
1000
Scientific Computing

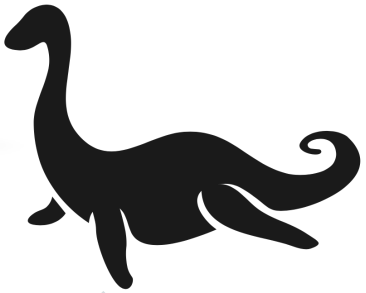
Nessie–
The First “Bone” of the Milky Way
© Stephen Alvarez www.picturestoryblog.com

The Milky Way

“Galactic Plane”

The Milky Way
(Artist's Conception)

COMPLETE



Star Formation

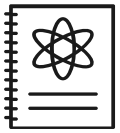
Data Visualization

Teaching & Outreach

Galactic Structure

Art

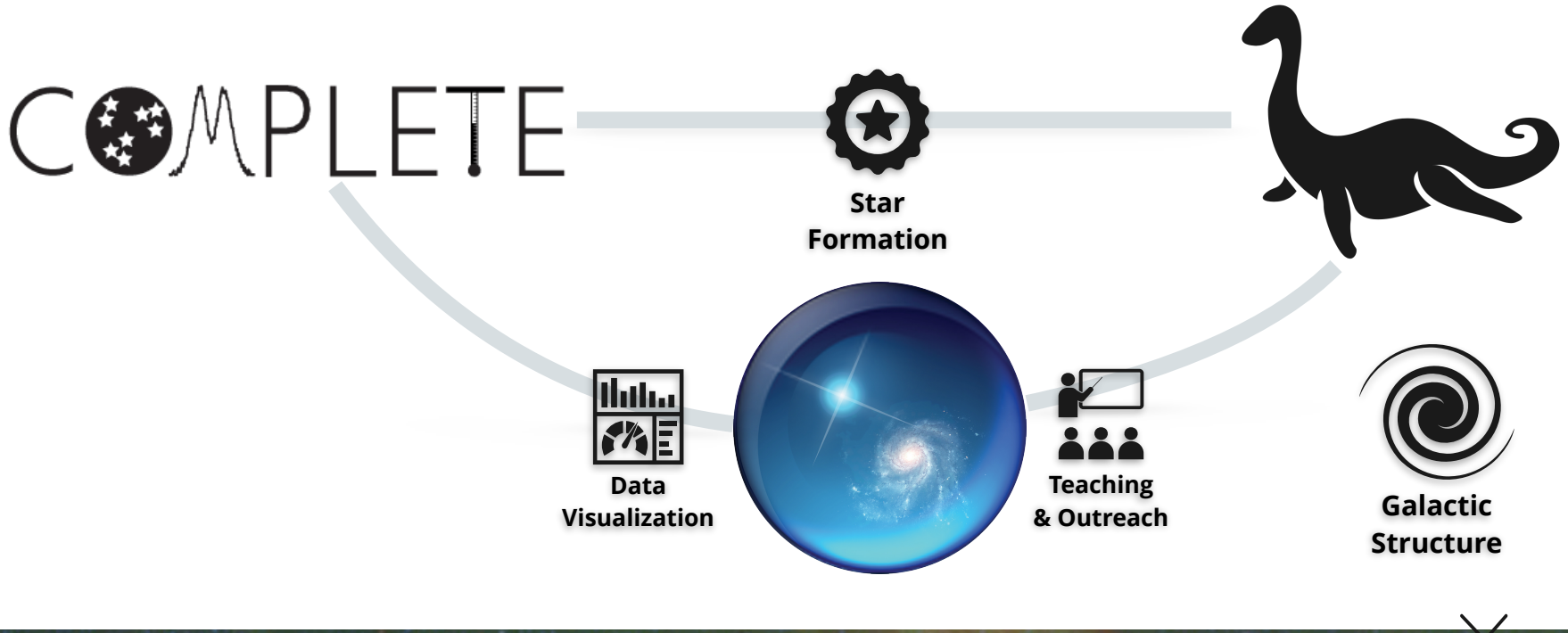
Science



(Hi)stories

Math

“Whoa!? Who ordered ‘bones’?!”



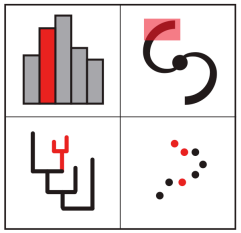
WorldWide Telescope *Stories*

Bones of the Milky Way

ORIGINS

EVOLUTION

This is a story about how a group of Astronomers found a new way to uncover the structure of our Galaxy, using WWT, in the backof a

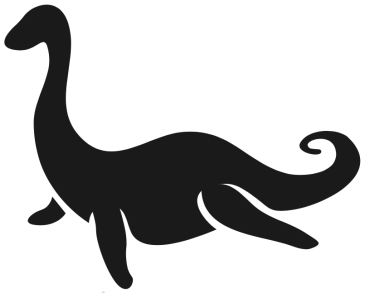


glue

multidimensional data exploration

Data Visualization

Scientific Computing

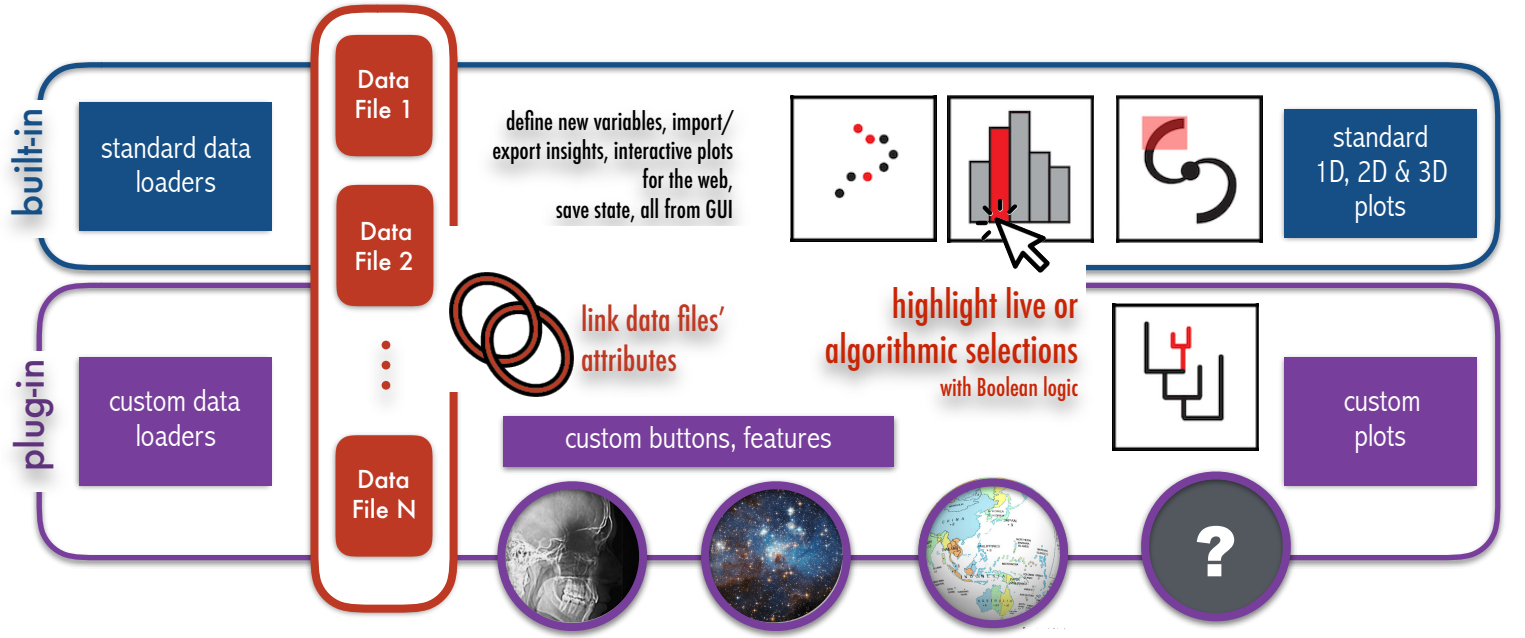


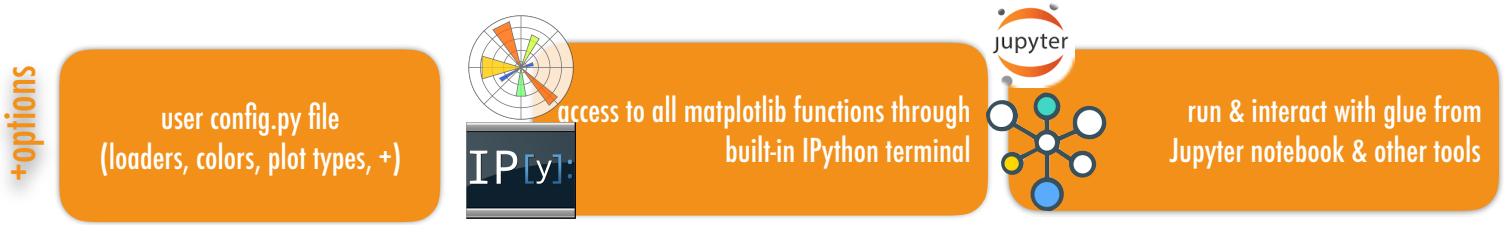
Galactic Structure

glue

multidimensional data exploration

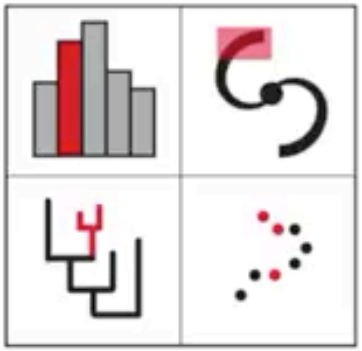
2011-





Multi-dimensional data exploration with

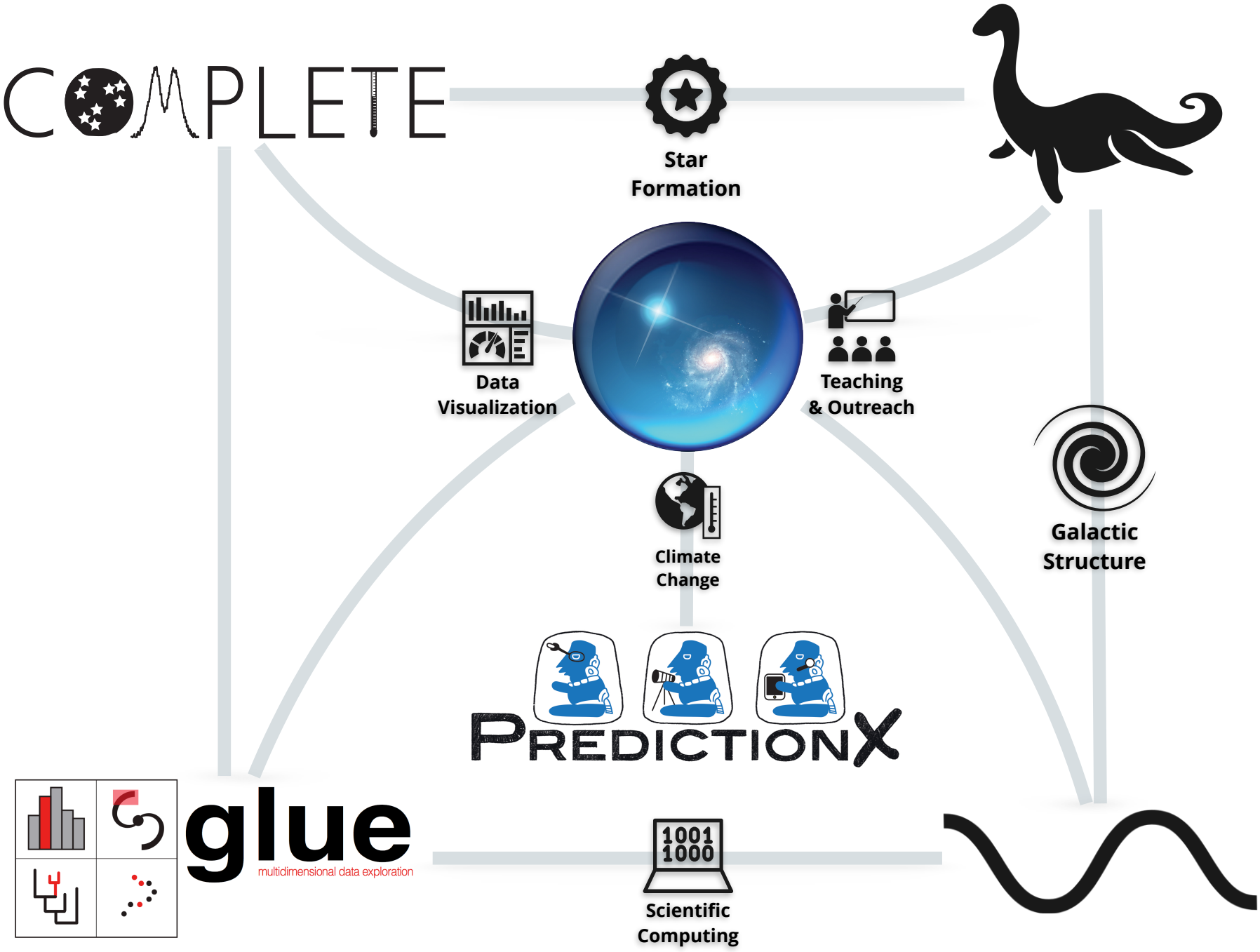
glue



http://www.glueviz.org

video by Tom Robitaille, lead glue developer

glue created by: C. Beaumont, M. Borkin, M Breddels, P. Qian, T. Robitaille, C. Zucker and A. Goodman, PI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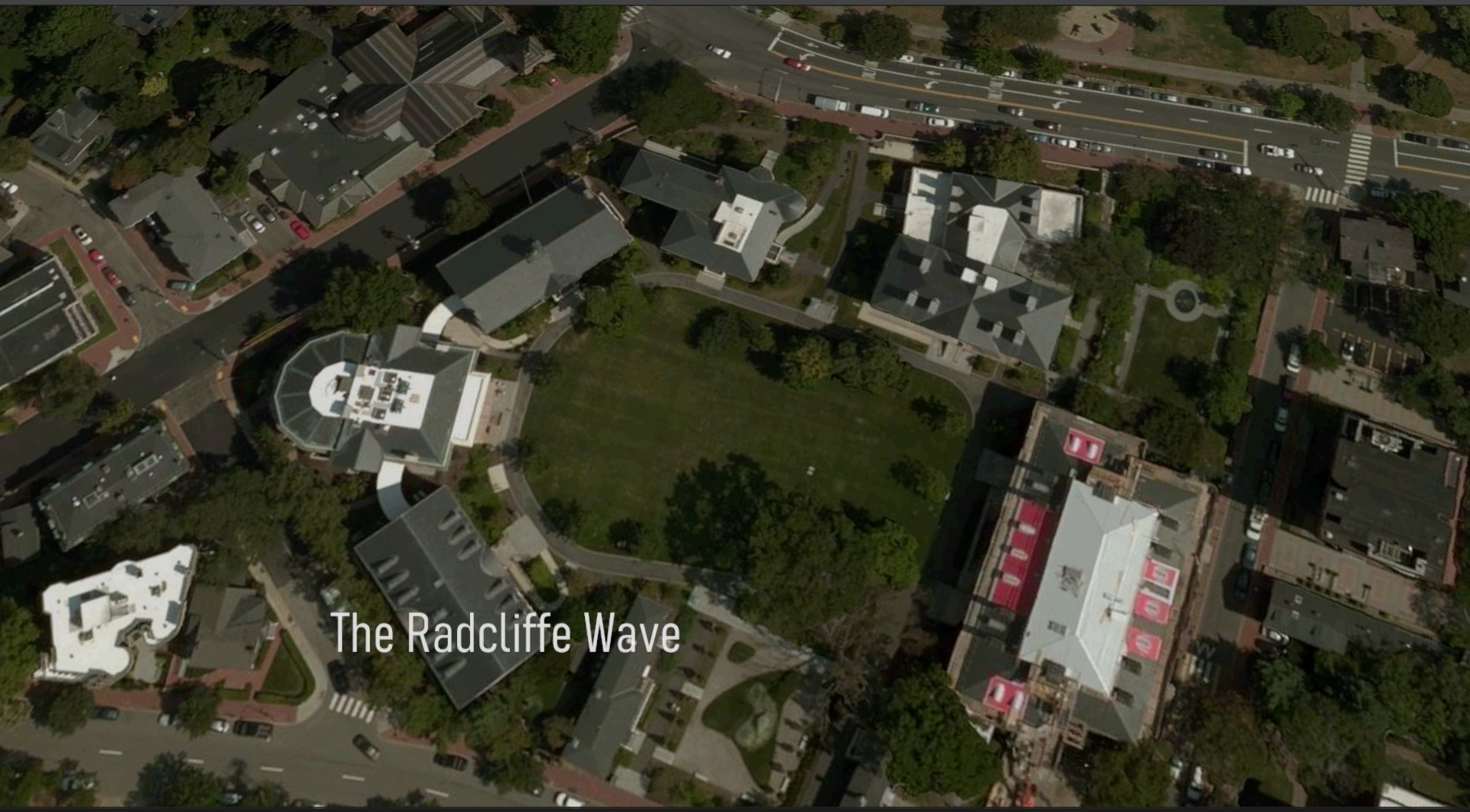
PREDICTIONX
glue
multidimensional data exploration
1001
1000
Scientific Computing



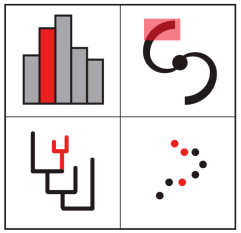
DRAFT PR video shows work of Radcliffe Fellow João Alves, GSAS student Catherine Zucker, AG++ (Nature, upcoming, embargoed)

The “Radcliffe” Wave 2019-

Data Visualization

Galactic Structure

RADCLIFFE INSTITUTE
FOR ADVANCED STUDY
HARVARD UNIVERSITY

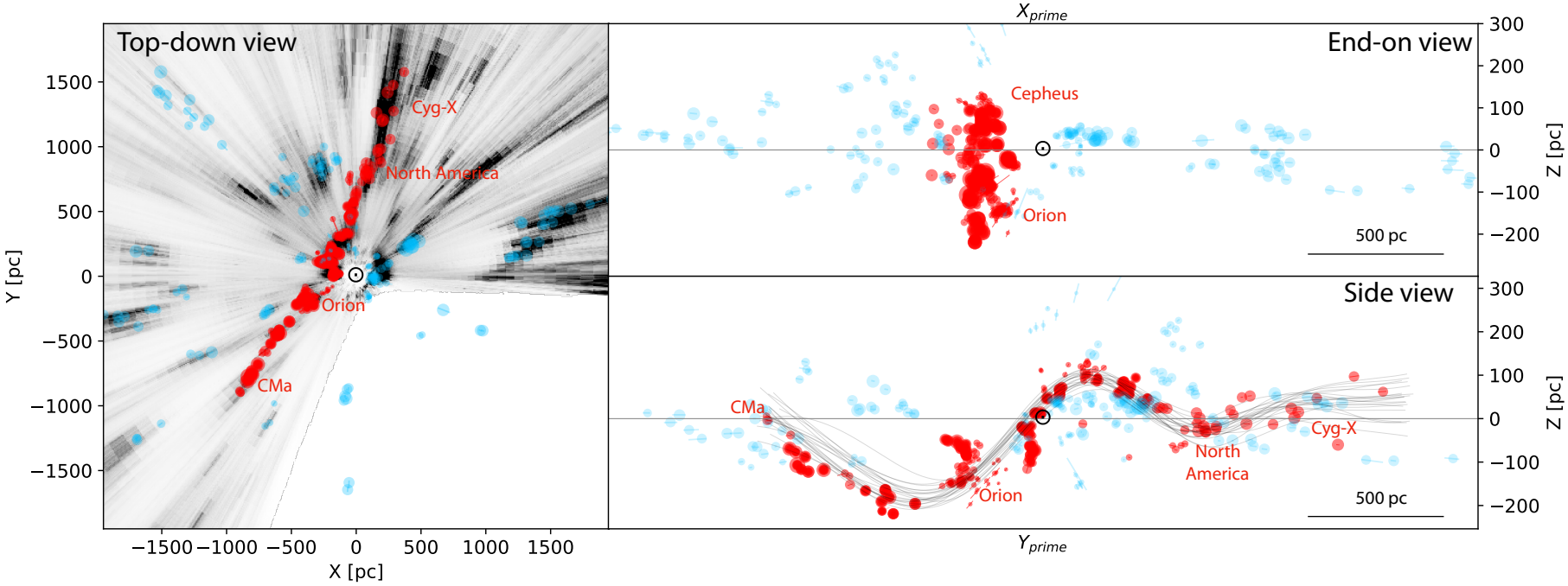


glue
multidimensional data exploration

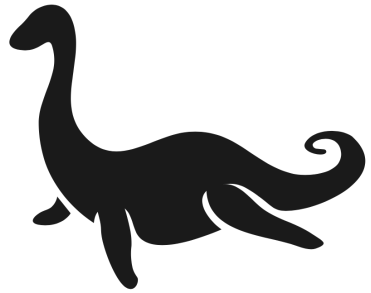
Scientific Computing

The “Radcliffe” Wave

(embargoed, please do not distribute)



João Alves, Catherine Zucker, Alyssa Goodman, Joshua Speagle, Stefan Meingast, Thomas Robitaille, Douglas Finkbeiner, Edward F. Schlafly, and Gregory Green, *Nature* (January 2020)



Galactic
Structure

Milky Way Structure Jargon (Cartoon!)

"Wave(s)"

Bone(s)

flaring

thick disk

bulge

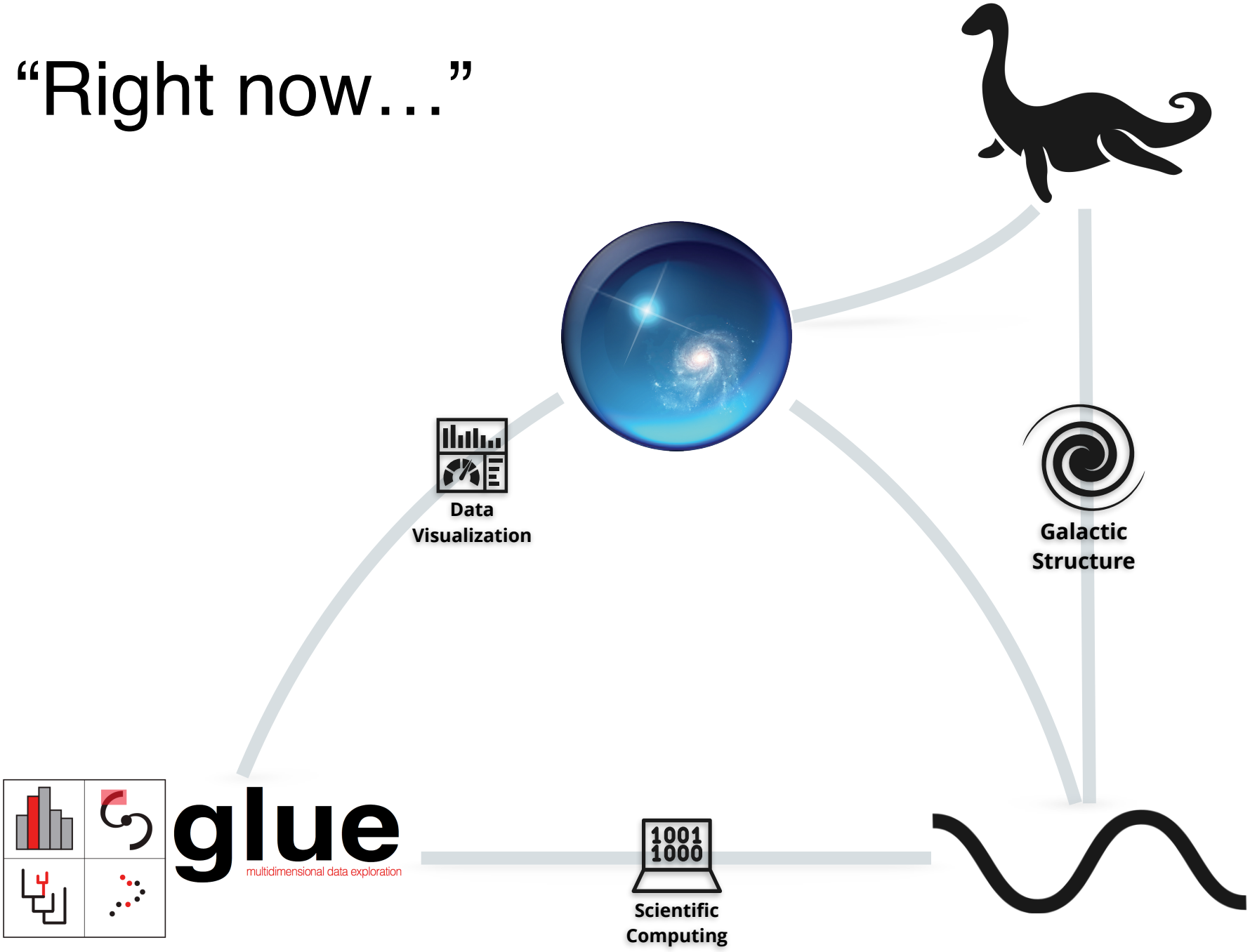
bar

thin disk

arms

halo

“Right now…”


Data
Visualization
Galactic
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1001
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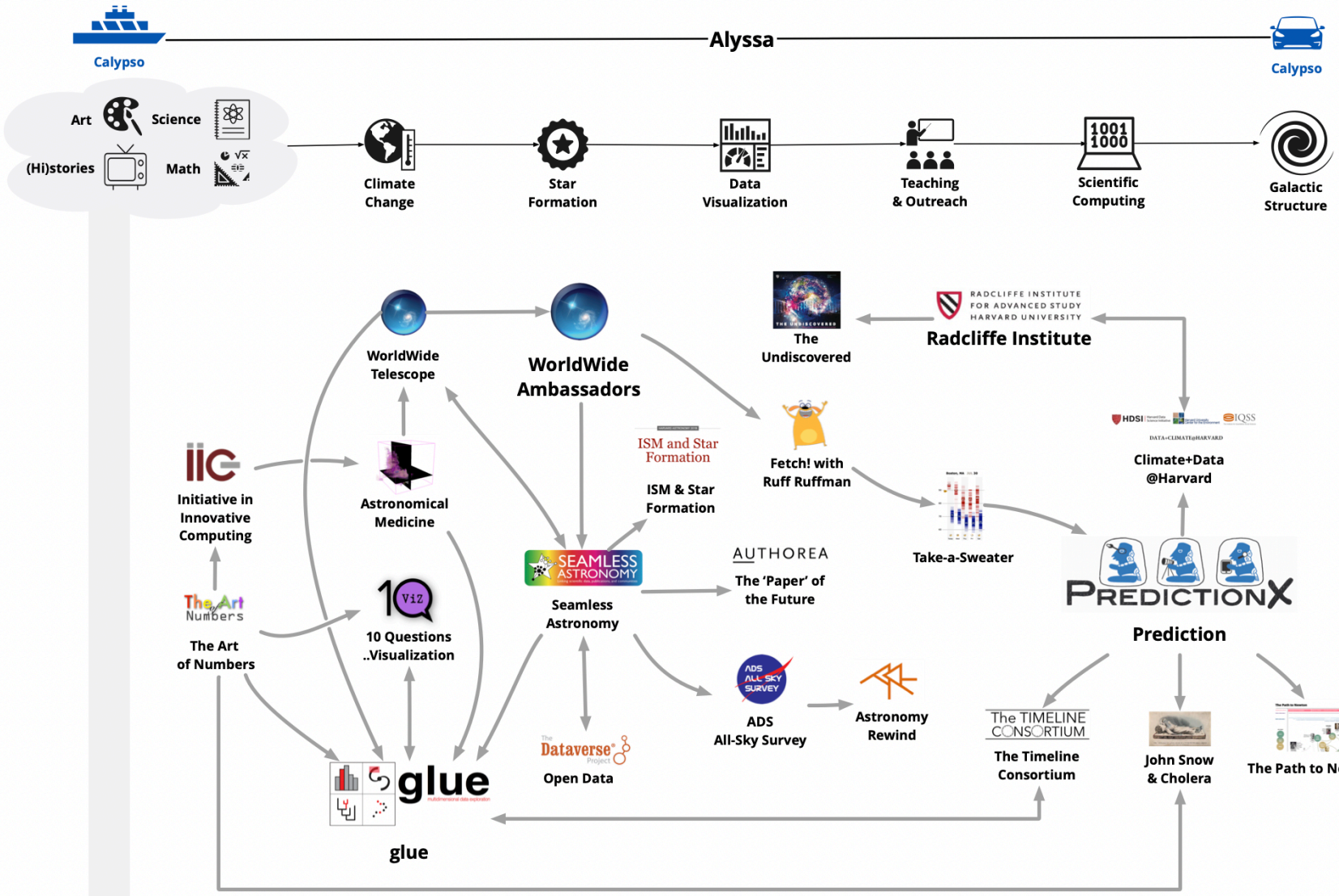
Calypso
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Fetch! with Ruff Ruffman
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The Art Numbers
The Art of Numbers
10 Questions ..Visualization
SEAMLESS ASTRONOMY
Seamless Astronomy
AUTHOREA
The 'Paper' of the Future
Take-a-Sweater
PREDICTIONX
Prediction
ADS ALL-SKY SURVEY
ADS All-Sky Survey
Astronomy Rewind
The TIMELINE CONSORTIUM
The Timeline Consortium
John Snow & Cholera
The Path to Newton
The Dataverse Project
Open Data
glue
glue
COMPLETE
The COMPLETE Survey of Star-Forming Regions
Nessie-Bones
"Radcliffe Wave"

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MPH
274 mi
8:57 AM
Alyssa
Calypso to Calypso
68
69