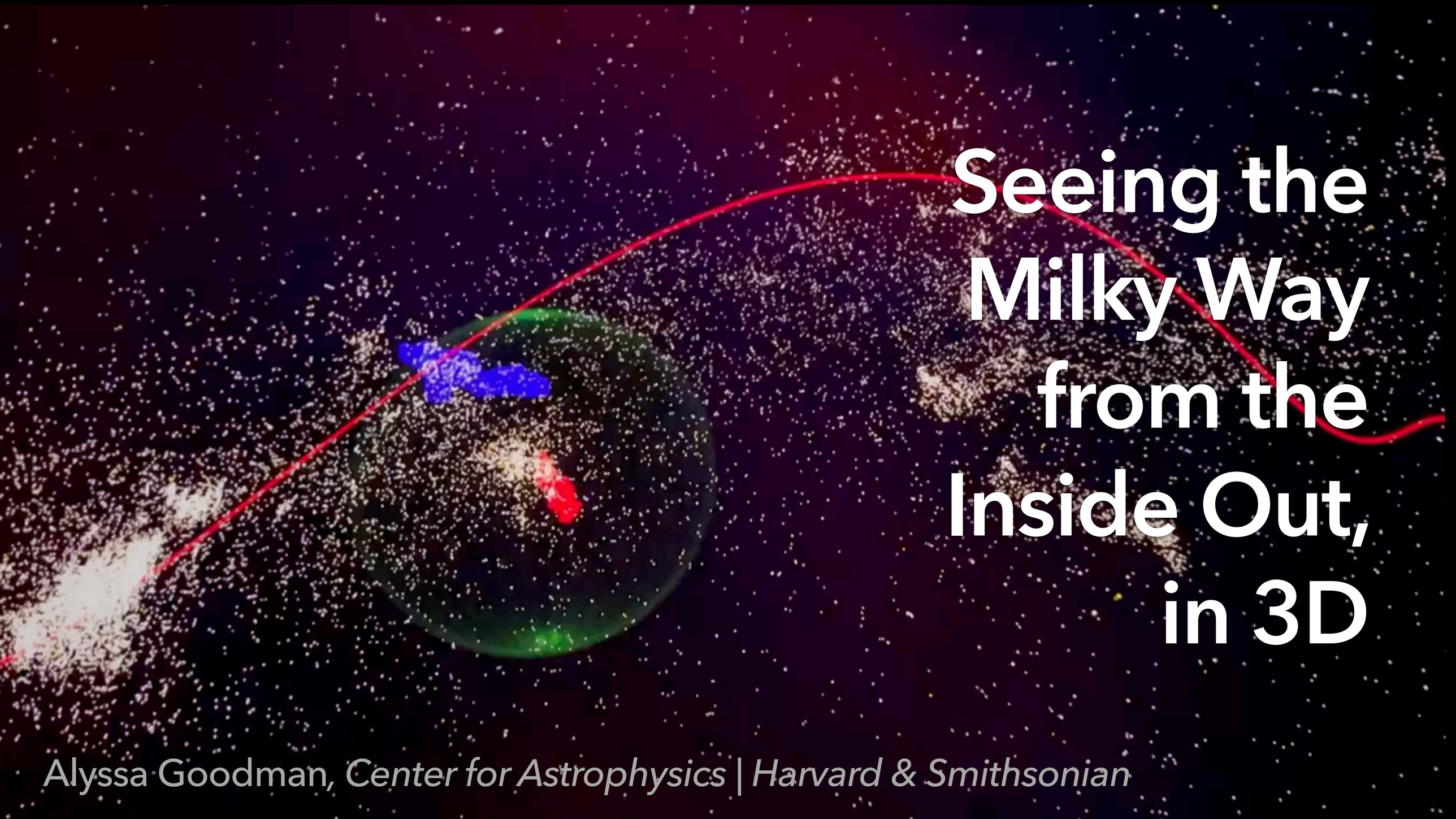


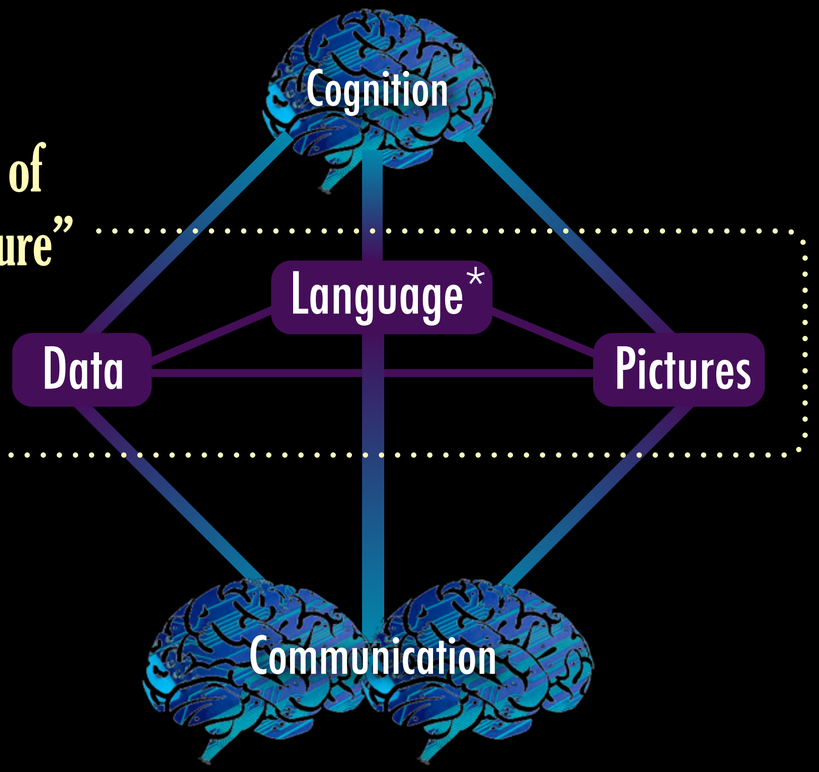
Seeing the Milky Way from the Inside Out, in 3D

Alyssa Goodman, *Center for Astrophysics | Harvard & Smithsonian*

2009

2015

"Paper of the Future"



*"Language" includes words & math

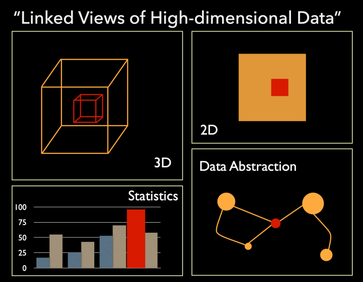
2024

LIVE

What's LIVE?

LIVE

Why Linked Views?



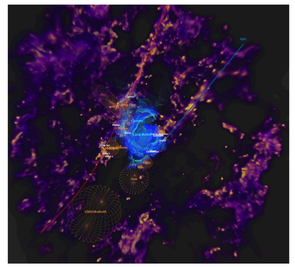
What's MilkyWay3D .org?

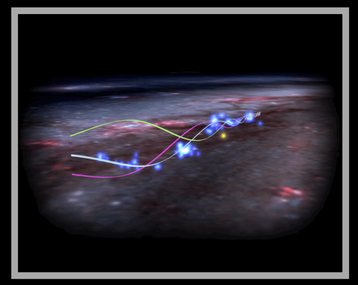
MILKYWAY3D.org

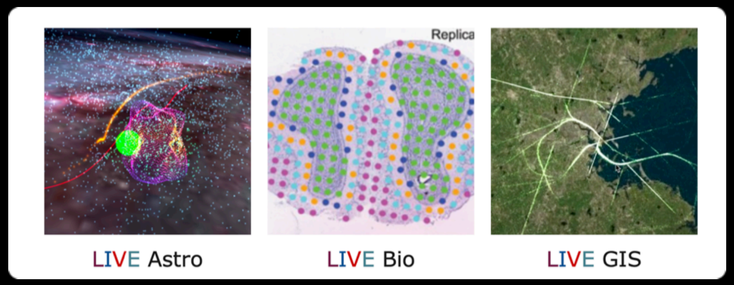
Why glue?

glue
multidimensional data exploration
glueviz.org

glue+3D dust maps= the "New" Milky Way







AR for Science and Outreach

glue→glupyter→LIVE-Astro, LIVE-Bio, LIVE-GIS

LIVE

LIVE-env.org

LIVE Environments

About LIVE | Capabilities | Tech | Who are we? | Learn More

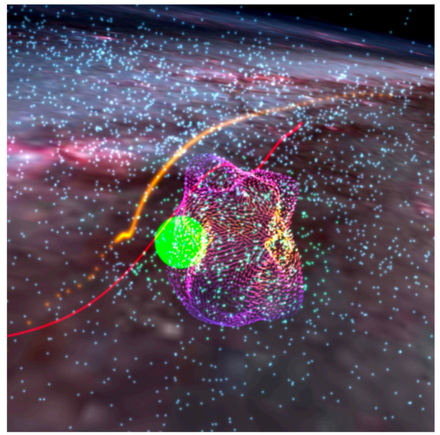
Linkable Interactive Visualization Exploration (LIVE) Environments

What is LIVE?

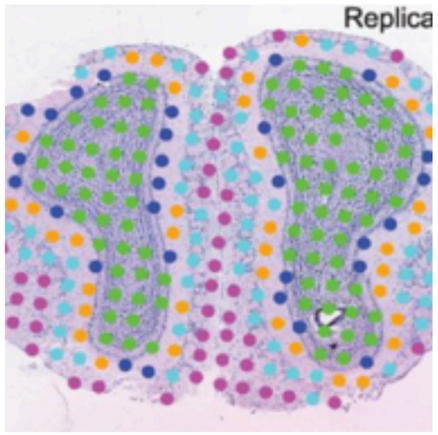
LIVE lets anyone build
"Linkable Interactive Visualization and Exploration" Environments.

LIVE is free, open-source, and helps with shared data and visualization challenges across astronomy (LIVE Astro), biology (LIVE Bio) and GIS (LIVE GIS).

As LIVE's infrastructure is being built, collaborators are ensuring its utility across Astronomy, Biology, and GIS by pursuing LIVE's science demonstration projects.



LIVE Astro



LIVE Bio

LIVE GIS

LIVE

LIVE-env.org

Who are we?

Organizations and people listed on this page are actively creating LIVE's foundational elements, more about our suport and upcoming requests for funding can be found at the Support page. Information here reflects collaboration details as of Jan 29, 2024, and is still subject to change.

Core Collaborators

Core collaborators have primarily responsibility for developing the foundational elements of the LIVE Environments and coordinating the project.

Core Organization	Group	(Lead) Participants	Expertise
Harvard University, Faculty of Arts & Sciences, Division of Science	glue	Prof. Alyssa Goodman	LIVE software coordination & **infras** proposal)
The Jackson Laboratory	Data Science, Computational Sciences	Prof. Ed Liu, Prof. Elissa Chesler	**biological applications** of LIVE to Digital Functional HistoPathology (Liu PI for ARPA-H); biology tools
University of California, Berkeley, Institute for Data Science	Jupyter Project	Prof. Fernando Perez Prof. Jennifer Chayes	**Jupyter leadership**, **GIS applications** and tools

Science Demonstration Leads

Each of the three LIVE Environments supports an associated science use case, lead by the Science Demonstration Leads.

Science Demo Organizations	Group	Lead	Expertise
Smithsonian Institution	Smithsonian Astrophysical Observatory (CfA)	Dr. Catherine Zucker	**astrophysical applications** of LIVE to our understanding of the **Milky Way galaxy** (PI of science proposal)
The Jackson Laboratory and Princeton University	Data Science, Bioinformatics & Functional Genomics	Prof. Ed Liu & Prof. Olga Troyanskaya	**biological applications** of LIVE to Digital Functional HistoPathology (PI of science proposal)
University of California, Berkeley, Institute for Data Science	Jupyter Project	Prof. Fernando Perez Prof. Jennifer Chayes	**Geospatial applications** of LIVE to our understanding **of climate change**

Affiliated Collaborators

- MIT, CSAIL
- Space Telescope Science Institute
- The American Museum of Natural History
- Princeton
- Northeastern University,
- Brigham & Women's Hospital
- Harvard University Paulson School of Engineering
- The Broad Institute of Harvard and MIT
- Harvard Medical School
- The Simons Foundation/Flatiron Institute

Software Contractors

- glue solutions, inc.
- Quantstack
- Widgetti.io

LIVE

LIVE-env.org

Creating a LIVE Environment is flexible and easy

1. choose a FRAMEWORK, using a TEMPLATE if you like

2. add visualization TOOLS (as-needed)

3. access/add DATA

4. LINK your data together

5. EXPLORE using linked visualizations

6. SHARE your interactive environment

LIVE

2. add visualization TOOLS (as-needed)

LIVE-env.org

Integrated into glue, prior to LIVI

matplotlib

The comprehensive library for creatin interactive visualizations in the deskt interactive visualizations in glue-jupy

bqplot

bqplot is a python based visualizatior interactive widget, making it easy to

WorldWide Telescope

WorldWide Telescope provides a tool large astronomical surveys, as well a the earth.

Sample planned integrations for L

Vega Lite

Vega-Lite is a high-level grammar of JSON syntax to create an expressive Here is an example live figure, and cl LIVE ❤ Vega Lite!

glue

python library to explore relationships within and between related datasets

Jdaviz

GUI-based tools link data visualization and interactive analysis(based on glue & Jupyter).

OpenSpace

interactive data visualization software designed to visualize the entire known universe.

WorldWide Telescope

a tool for showcasing astronomical data and knowledge

astropy

A community effort to develop a common core package for Astronomy in Python and foster an ecosystem of interoperable astronomy packages

ESA Sky

allows visualization and download public astronomical data (cf. Aladin)

CARTA

Cube Analysis and Rendering Tool for Astronomy image visualization and analysis tool designed for the ALMA, the VLA, & SKA

Aladin Lite

lightweight version of the Aladin tool, running in the browser and geared towards simple visualization of a sky region

MAST

The Mikulski Archive for Space Telescopes is an astronomical data archive focused on the optical, ultraviolet, and near-infrared

Astro Data Lab

The overall goal of Astro Data Lab is to enable efficient exploration and analysis of the large datasets now being generated by instruments on NOIRLab and other wide-field telescope

TOPCAT

does what you want with tables

js9

brings astronomical image display to your browser and desktop

LIVE Astro

vaex

python library

K3D

Jupyter Notebook 3D visualization

yt

python package for

LIVE

LIVE-env.org

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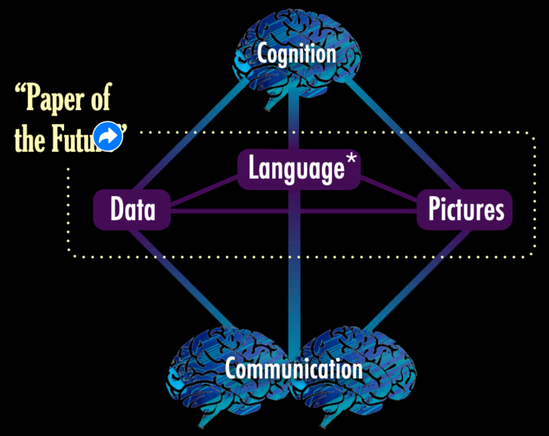


LIVE-env.org

6. SHARE your interactive environment

Interactive Exports

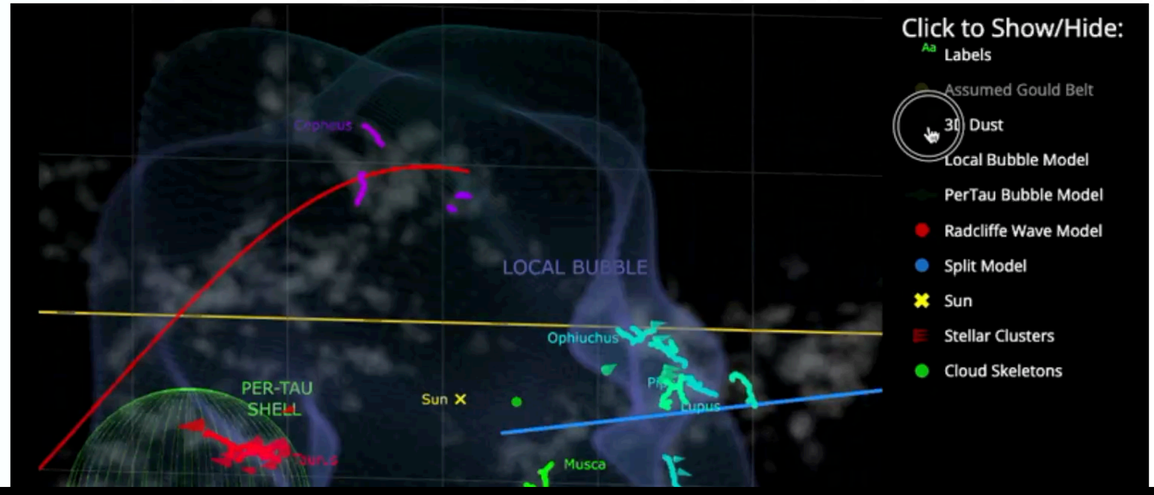
Visualizations can be exported as standalone interactive figures for embedding in webpages, public presentations, and scientific journals. Once LIVE is fully built-out, selected views from LIVE Environments (e.g. using Solara Server), will also be directly share-able in both scholarly and popular outlets.

Webpages for sharing science

Star Formation on the Local Bubble, as seen in *Nature*, 2022

The discovery that the 1000-light-year-wide "Local Bubble" surrounding the Sun and Earth is responsible for the formation of all nearby, young stars was first presented in a paper published in Nature on January 12, 2022, by Zucker et al. The paper's exploratory visualization, and figures like the interactive sample below, all relied on the glue software. The interactive figures were singled-out as a key innovation in much of the media coverage, including a feature in the New York Times.

Below is a gif showing some of the available interactions from one of the key figures from this paper; the full interactive figure is here.



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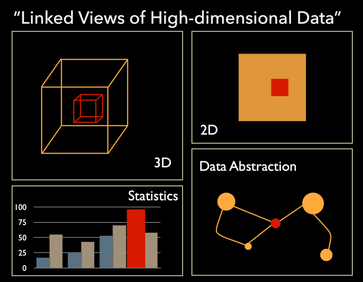
LIVE

Why Linked Views?



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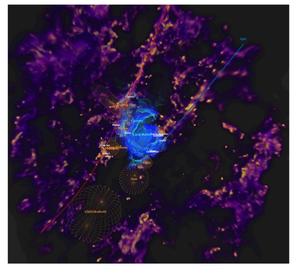
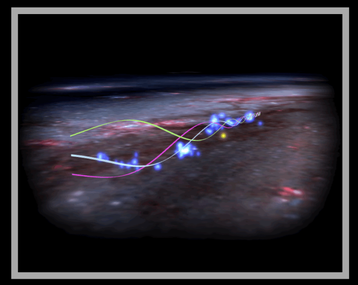
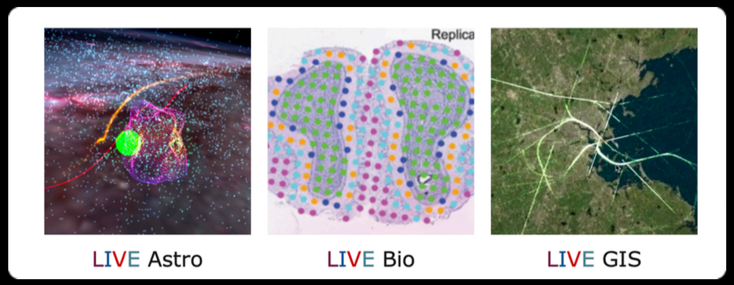


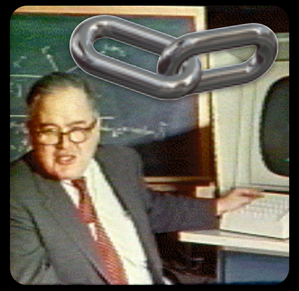




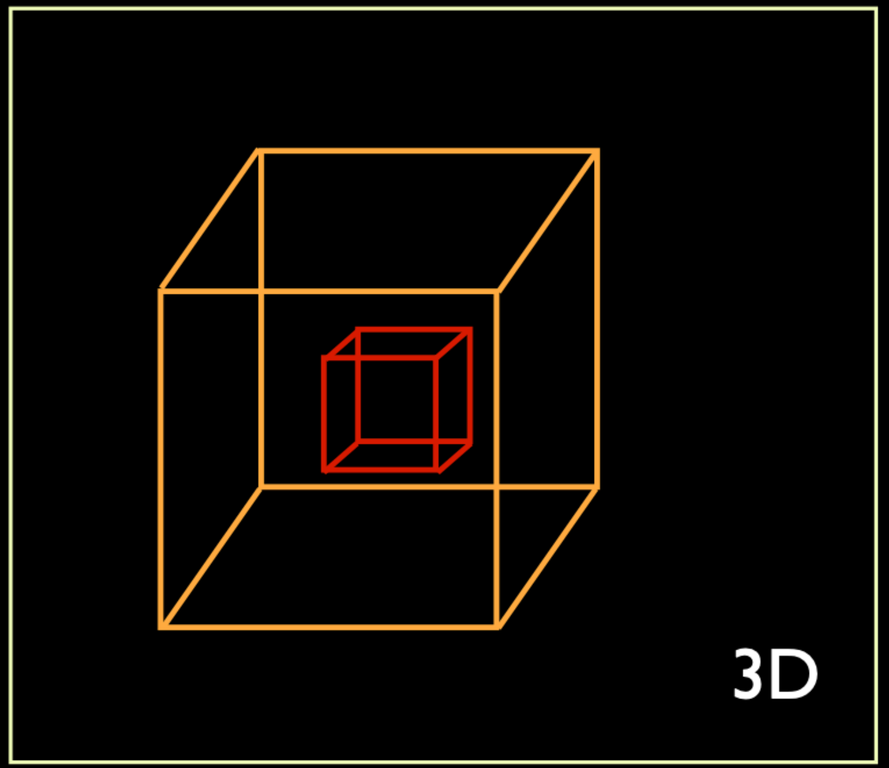
AR for Science and Outreach

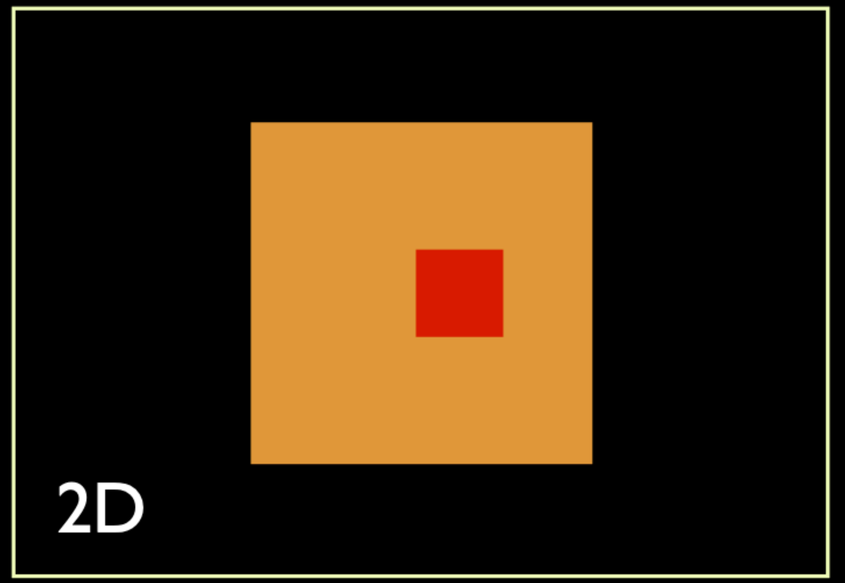
glue→glupyter→LIVE-Astro, LIVE-Bio, LIVE-GIS

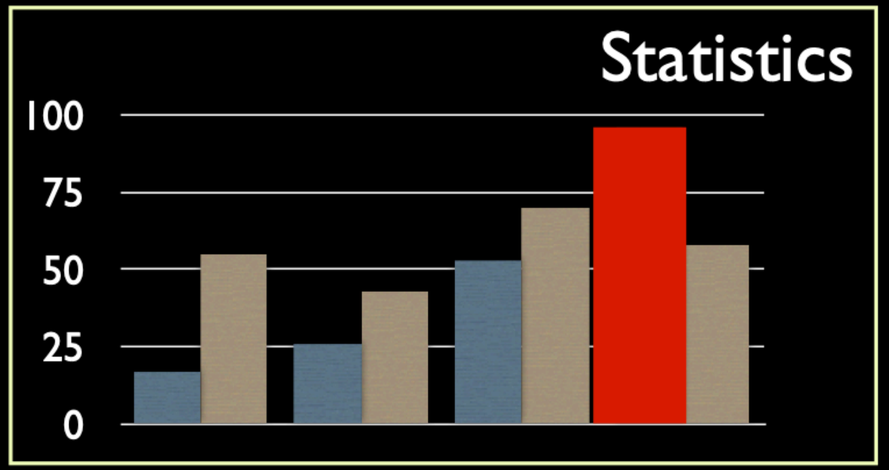
"Linked Views of High-dimensional Data"

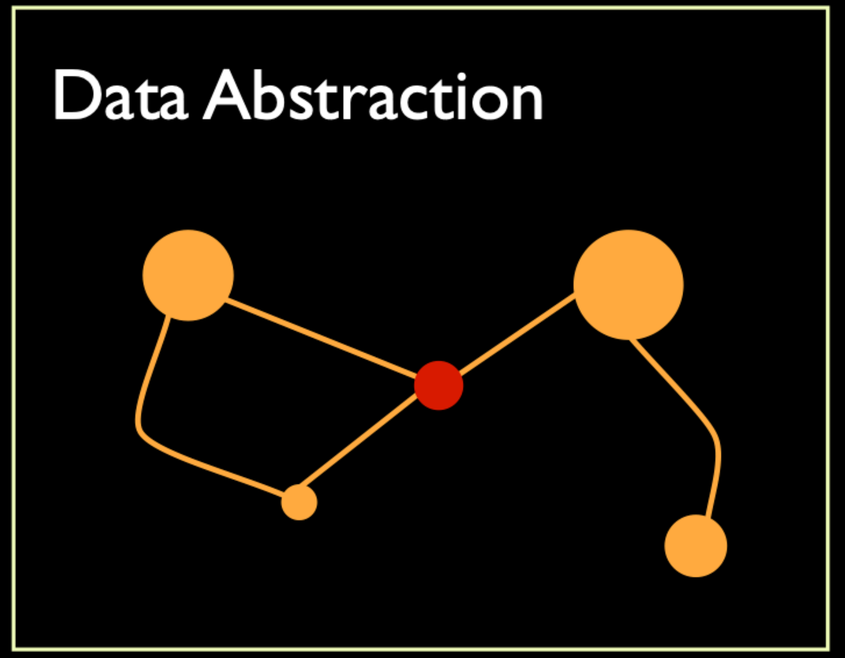


John Tukey



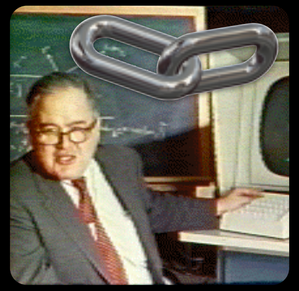






figure, by M. Borkin, reproduced from Goodman 2012, "Principles of High-Dimensional Data Visualization in Astronomy"

JOHN TUKEY'S LEGACY



John Tukey

PRIM-9

PRIM-H

DataDesk®

glue
multidimensional data exploration
glueviz.org

LIVE

XGobi → GGobi

RGGobi

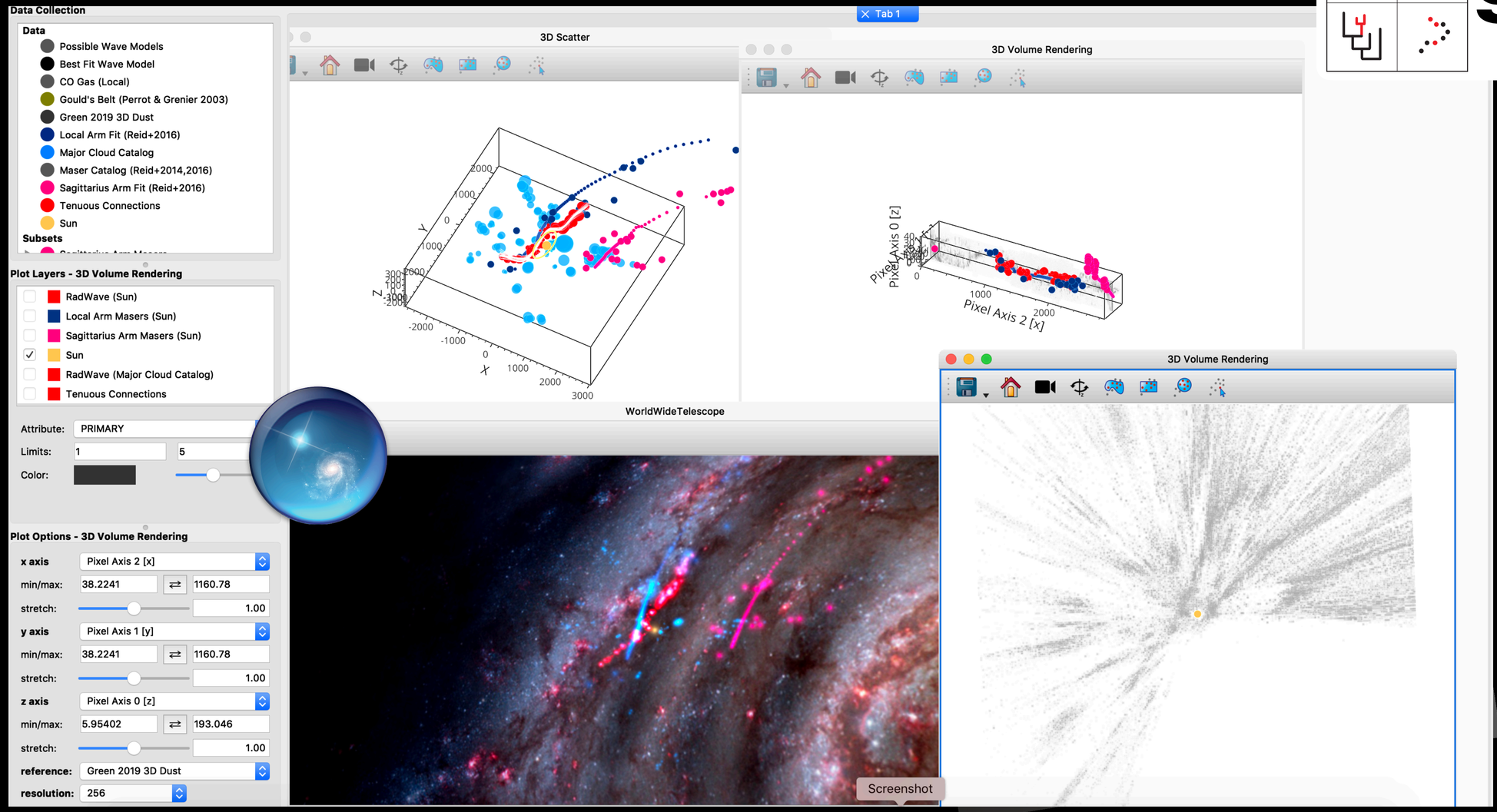
Spotfire®

Polaris → tableau SOFTWARE

IEEE VIS established

1970 1980 1990 2000 2010 2020

“Seeing” The Radcliffe Wave, in 3D



glue
multidimensional data exploration
glueviz.org

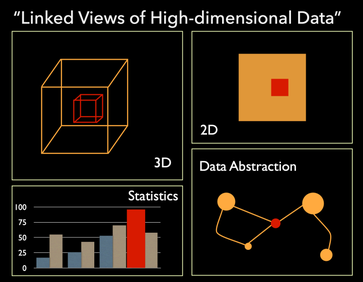
AAS WorldWide Telescope: worldwidetelescope.org

glue: glueviz.org

What's LIVE?

LIVE

Why Linked Views?



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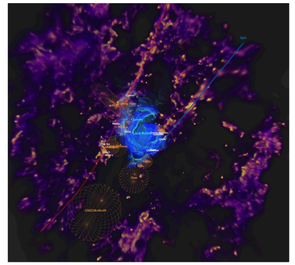

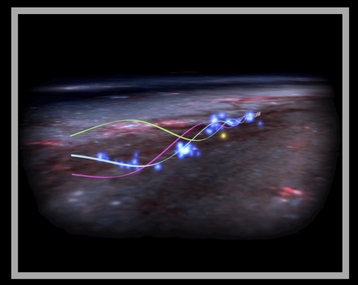

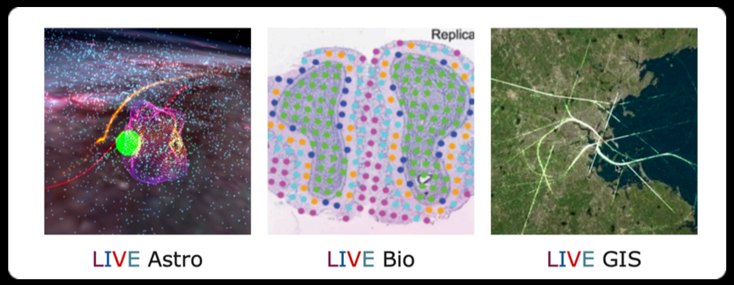

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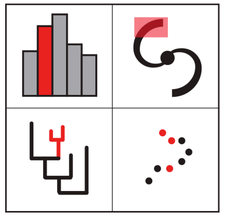
What is  glue?

multidimensional data exploration

It’s not an acronym.

It is open-source software that

glues data,

glues graphs &

glues tools.

data

numbers (tables, arrays, spreadsheets)

images & maps (FITS, JPEG, GIS and more)

data cubes (3D, 4D, and more)

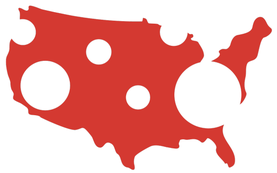
data files' common attributes are **glued**

avoiding the need to merge data files

“graphs”

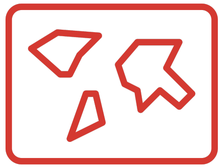
common statistical graphics

(scatterplots, histograms, tables, curves, overlays)



maps & images

(greyscale, color, contours, layer control…)

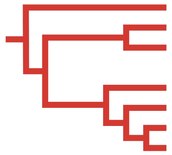


3D displays

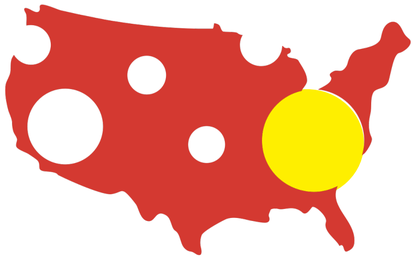
(scatter plots, volumetric rendering, sliders…)

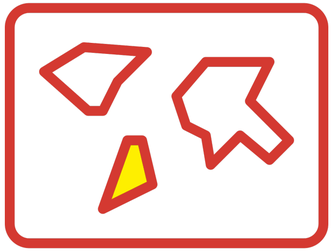
specialized & custom charts

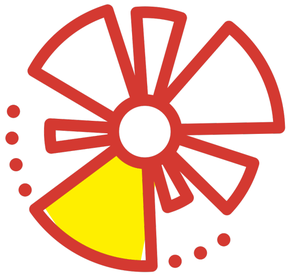
(dendrograms, polar plots, + domain-specific options)



selections propagate across all graphs



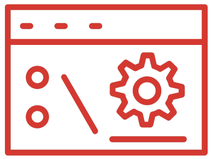




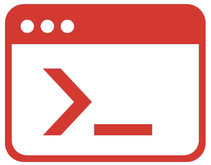
for real-time data exploration & insight

tools

plug-ins (user-defined formats, plots, layouts…)

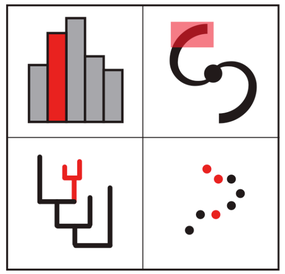


web services (across domains)



command-line (built-in terminal, scriptable)

for easy customization



glue

multidimensional data exploration

glues data,
glues graphs &
glues tools.

glueviz.org

BONUS: **save**, **share**, or **publish** what you learn—

save “sessions” to continue where you left off

export graphics

use/export to Jupyter environments

export to plot.ly (javascript)

export to augmented reality

learn how at glueviz.org.

glueviz.org

supported by

glue solutions inc.

GORDON AND BETTY MOORE FOUNDATION

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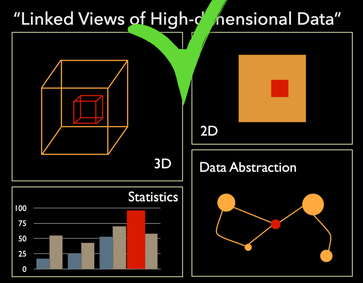

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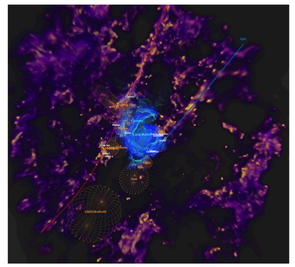
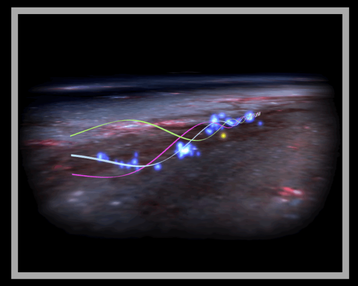
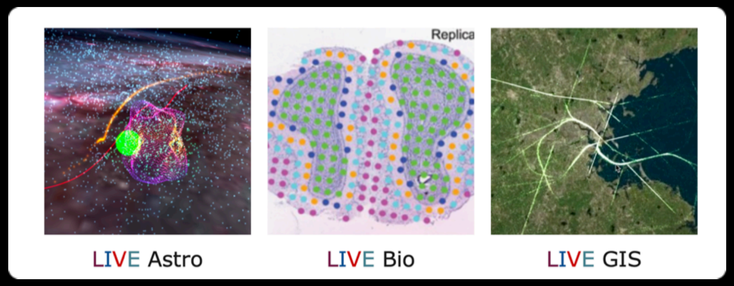






AR for Science and Outreach

glue→glupyter→LIVE-Astro, LIVE-Bio, LIVE-GIS

MILKYWAY3D.org

SCAN ME

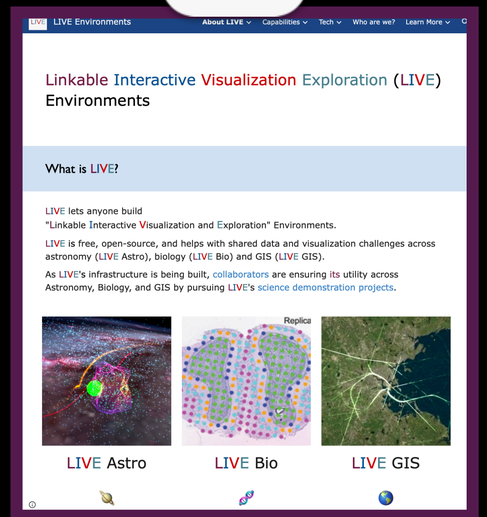
Welcome to a new view of the Milky Way... in 3D!

MilkyWay3D.org is an open-data open-source discovery hub, providing data, visualization, and research tools for studying the MilkyWay in 3D.

INFRASTRUCTURE ⟷ SCIENCE ⟷ EDUCATION & OUTREACH

INFRASTRUCTURE

LIVE



assembling data as a community, using modern, open-source practices

glue — glueviz.org

AMERICAN ASTRONOMICAL SOCIETY WORLDWIDE TELESCOPE — OpenSpace

linking position and motion across dimensions, using the modular architecture enabled by LIVE

(LIVE-Astro elements include glue, WWT, OpenSpace & more)

MAST — The Dataverse Project — DIGITAL universe

making data accessible online for decades

Lead: Alyssa Goodman, CfA

SCIENCE

enabling studies of how galaxies turn gas into stars, using...

stellar positions, clusters, motions

topology, positions & motions of (long) features

tracers of feedback & magnetic fields

details on star-forming regions...and more!

Lead: Catherine Zucker, CfA

EDUCATION & OUTREACH

connecting real research data, software, and science to learners

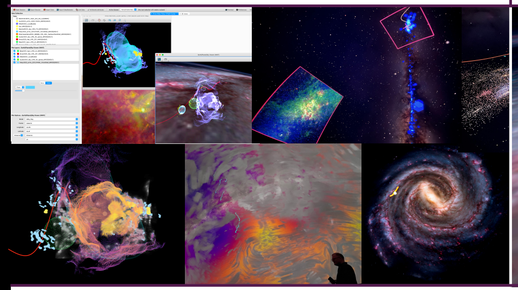
OpenSpace

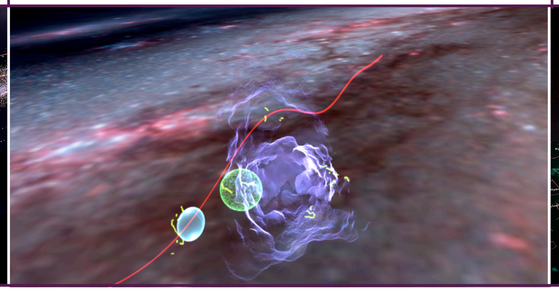
real-time data exploration anywhere, including in planetaria

CosmicDS

"Cosmic Data Stories" teach data science using astronomical data & tools

Lead: Jackie Faherty, AMNH

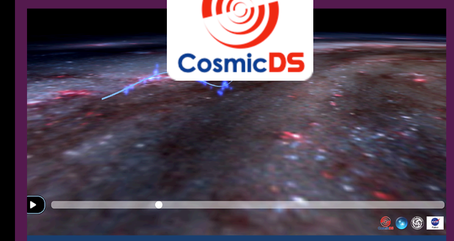




TEAM: Harvard/Smithsonian CfA (Jonathan Carifio, Alyssa Goodman, Ralf Konietzka, Theo O'Neill, Patricia Udomprasert, Catherine Zucker), **AMNH** (Brian Abbott, Micah Acinapura, Carter Emmart, Jackie Faherty); **Linkoping University** (Alex Bock) ; **University of Vienna** (Joao Alves, Sebastian Ratzenbock); **glue solutions, inc./Aperio** (Thomas Robitaille); **University of Wisconsin, Whitewater** (Bob Benjamin), **STScI/Johns Hopkins** (Josh Peek), **Max Planck IfA** (Gordian Edenhofer); **Northeastern University** (Michelle Borkin); and YOU?!

EDUCATION & OUTREACH

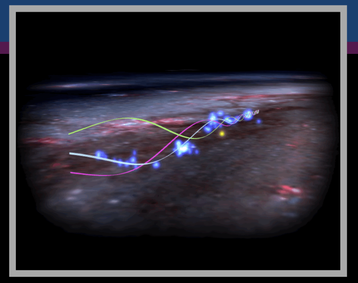
CosmicDS



RadWave in Motion

The RadWave is made up of gas, dust, and stars loosely connected in a wave-like shape. It is so huge and so close to us that earlier scientists did not see that these parts were all connected.

Learn more about the discovery of the RadWave here!



Just in case you want to win the jargon/history/context prize at the end…

+extra credit: The James Webb Space Telescope (JWST) “Jdaviz” tools are built using “glupyter”

2008 — 2012 — 2022 — 2023

“MilkyWay3D.org" is the “demonstration Project for “LIVE-Astro,” which builds on our earlier work on first, WorldWide Telescope, then glue

WORLDWIDE TELESCOPE

esa ESASky

Fachhochschule Nordwestschweiz

Public talk organized by the **Institute of Interactive Technologies**

Seeing the Milky Way from the Inside Out, in 3D

on 11 July, 12:00*, 5.1A17

Free attendance, registration not required

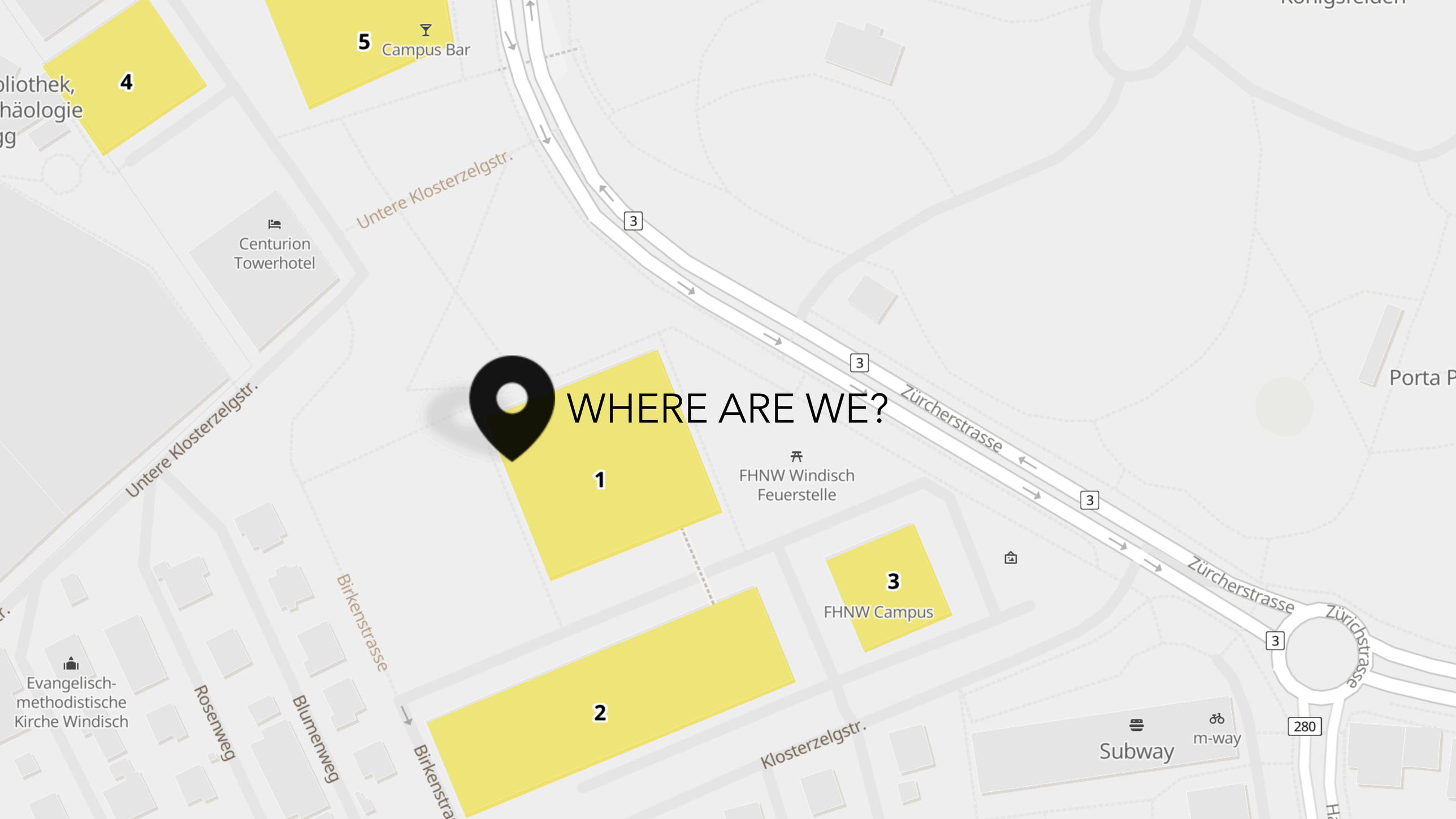
by **Prof. Dr. Alyssa Goodman**
Harvard University

The new "LIVE" collaboration (see live-env.org) is creating open-source software environments that let anyone build "Linkable Interactive Visualization and Exploration" Environments.

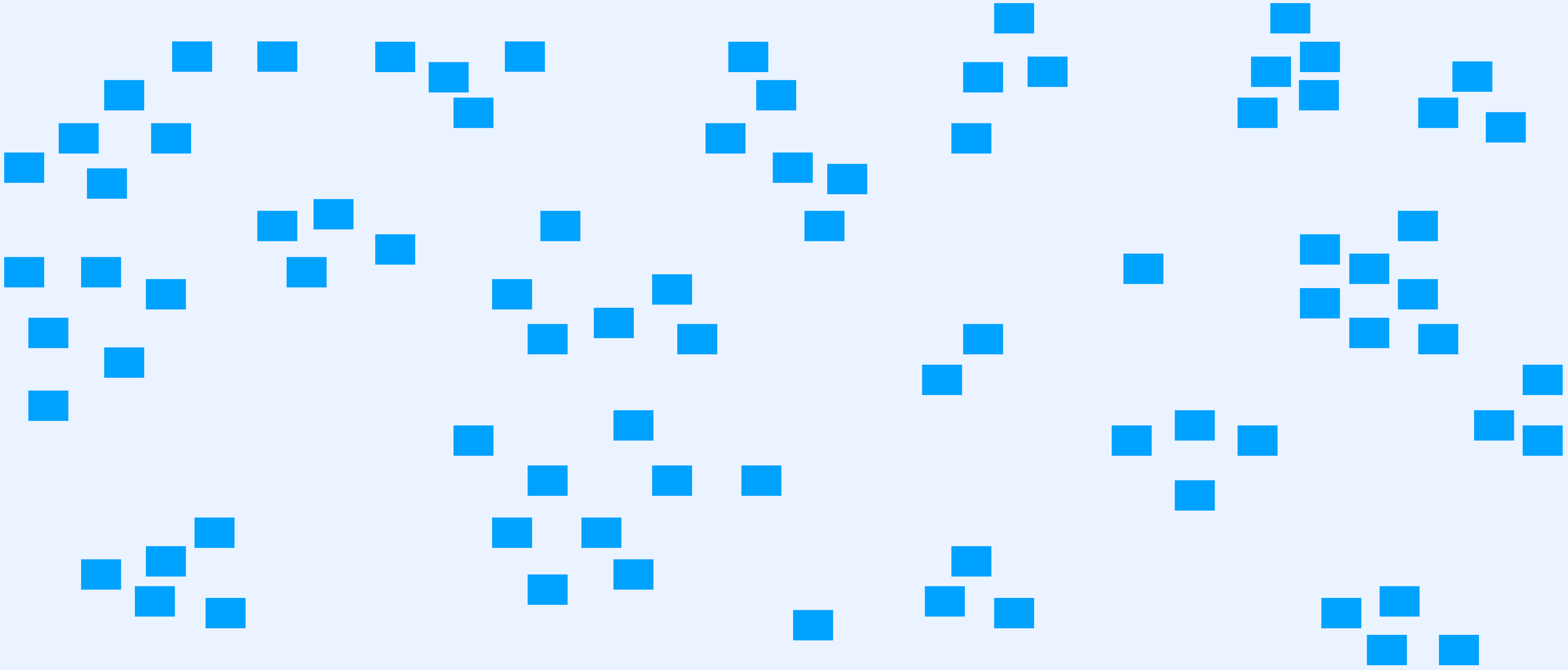
Prof. Dr. Goodman will explain LIVE's history and goals, highlighting "MilkyWay3D.org," which is creating an open-science resource for studying the 3-dimensional structure of our Milky Way galaxy using LIVE-Astro. She will also demonstrate the transferability of LIVE's components with views of additional applications in e.g., Biology and Geographic Information Science.

* We will offer sandwiches, "first come first served".

WHERE ARE WE?

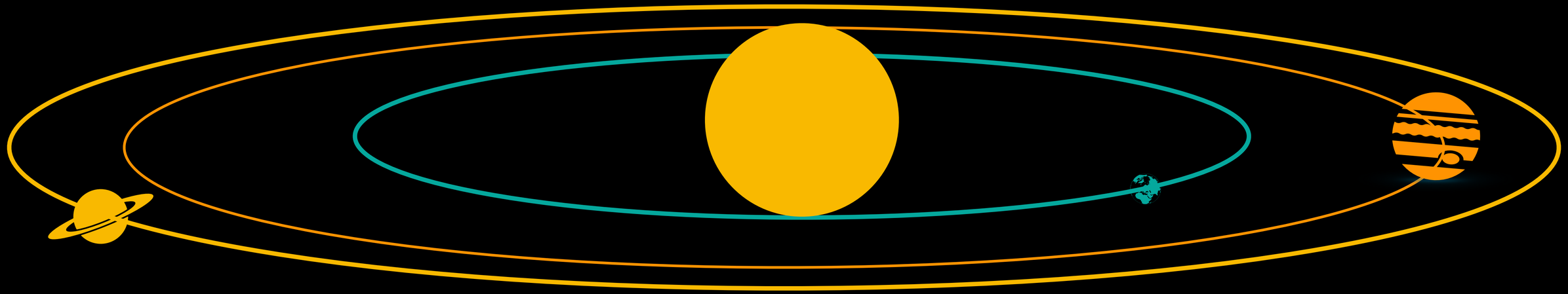

WHERE ARE WE?
1
2
3
4
5
FHNW Windisch
Feuerstelle
FHNW Campus
Campus Bar
Centurion
Towerhotel
Untere Klosterzelgstr.
Zürcherstrasse
Zürichstrasse
Birkenstrasse
Klosterzelgstr.
Rosenweg
Blumenweg
Evangelisch-
methodistische
Kirche Windisch
Subway
m-way
3
280

WHERE ARE WE?



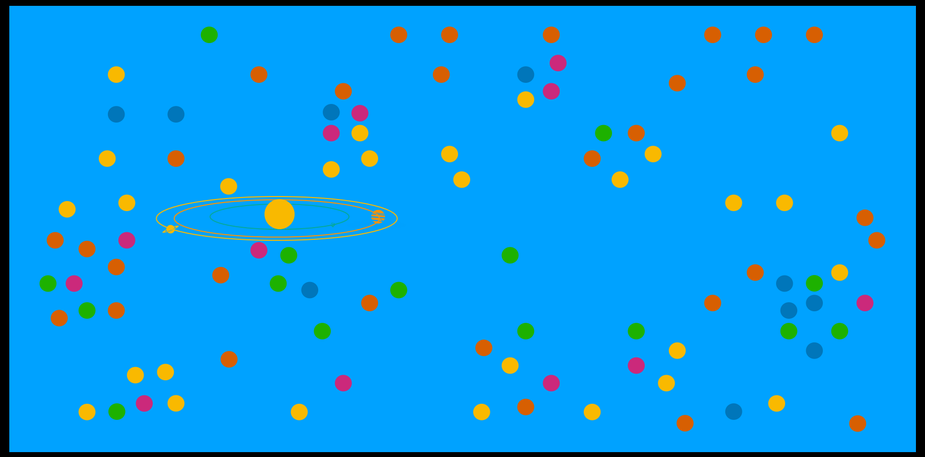
our **Universe** contains MANY billions of **galaxies**

ours is called “The Milky Way” and it contains about 1 hundred billion stars

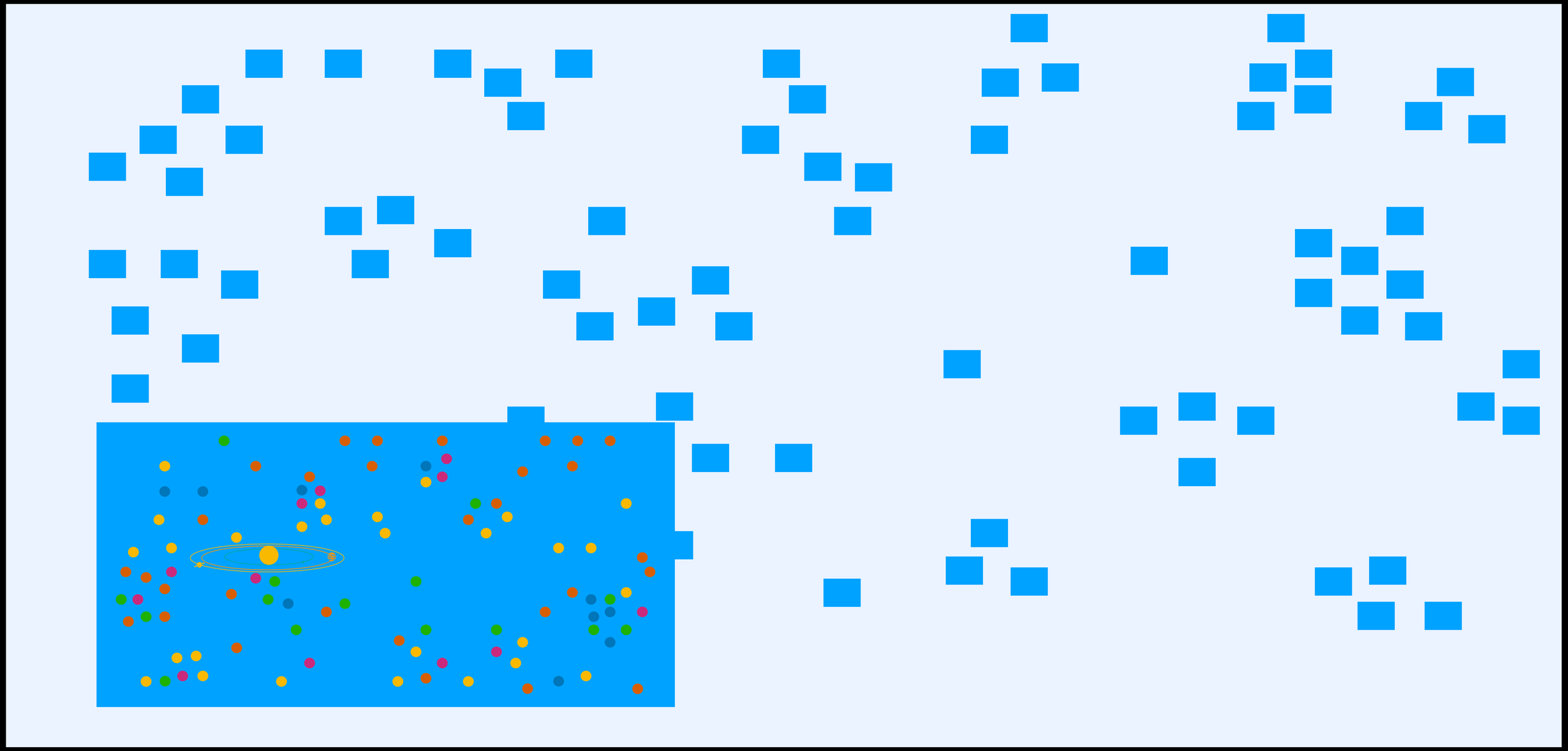


around most of the stars are systems of planets (ours is called “**The Solar System**”)

our home planet is **Earth**

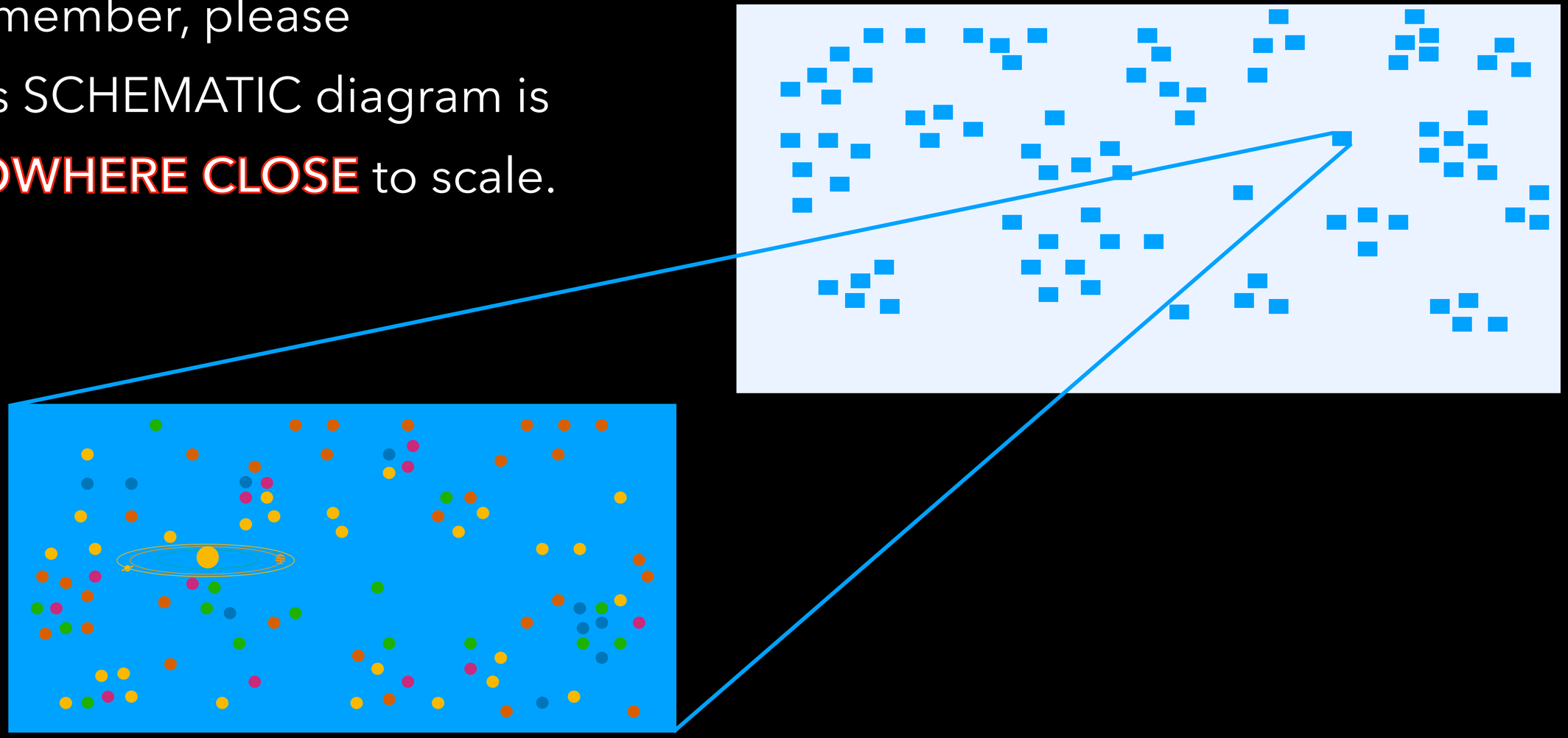


Earth resides in the Solar System, around the Sun, which is one of MANY stars,
INSIDE the Milky Way,



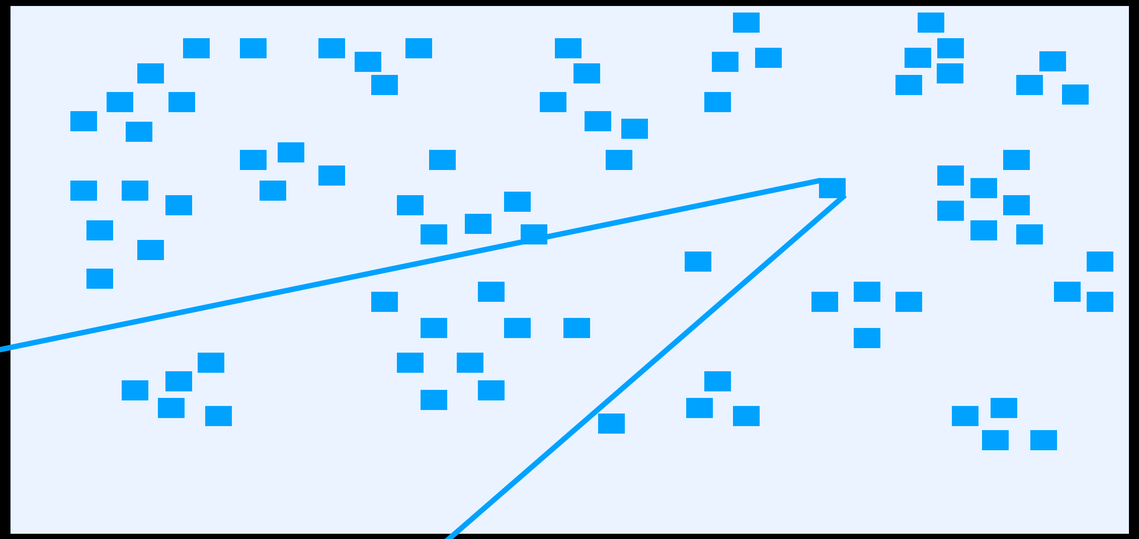
Earth resides in the **Solar System**, around the **Sun**, which is one of MANY **stars**, INSIDE the **Milky Way**, which is one of MANY **galaxies**, in our **Universe**

Remember, please
this SCHEMATIC diagram is
NOWHERE CLOSE to scale.



Earth resides in the **Solar System**, around the **Sun**, which is one of MANY **stars**,
INSIDE the **Milky Way**, which is one of MANY **galaxies**, in our **Universe**

And, actually, that boring blue box likely looks something more like this…



…cartoon!

…and we are buried INSIDE the Milky Way.

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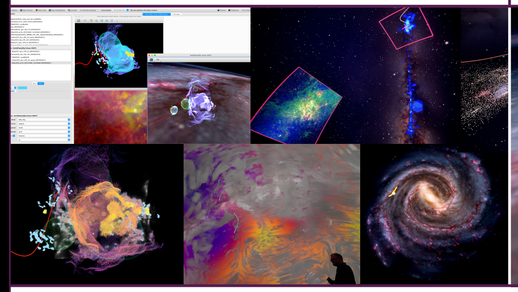

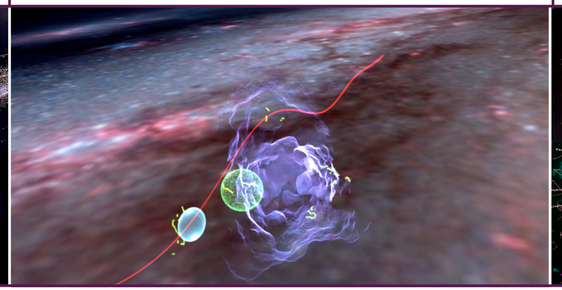

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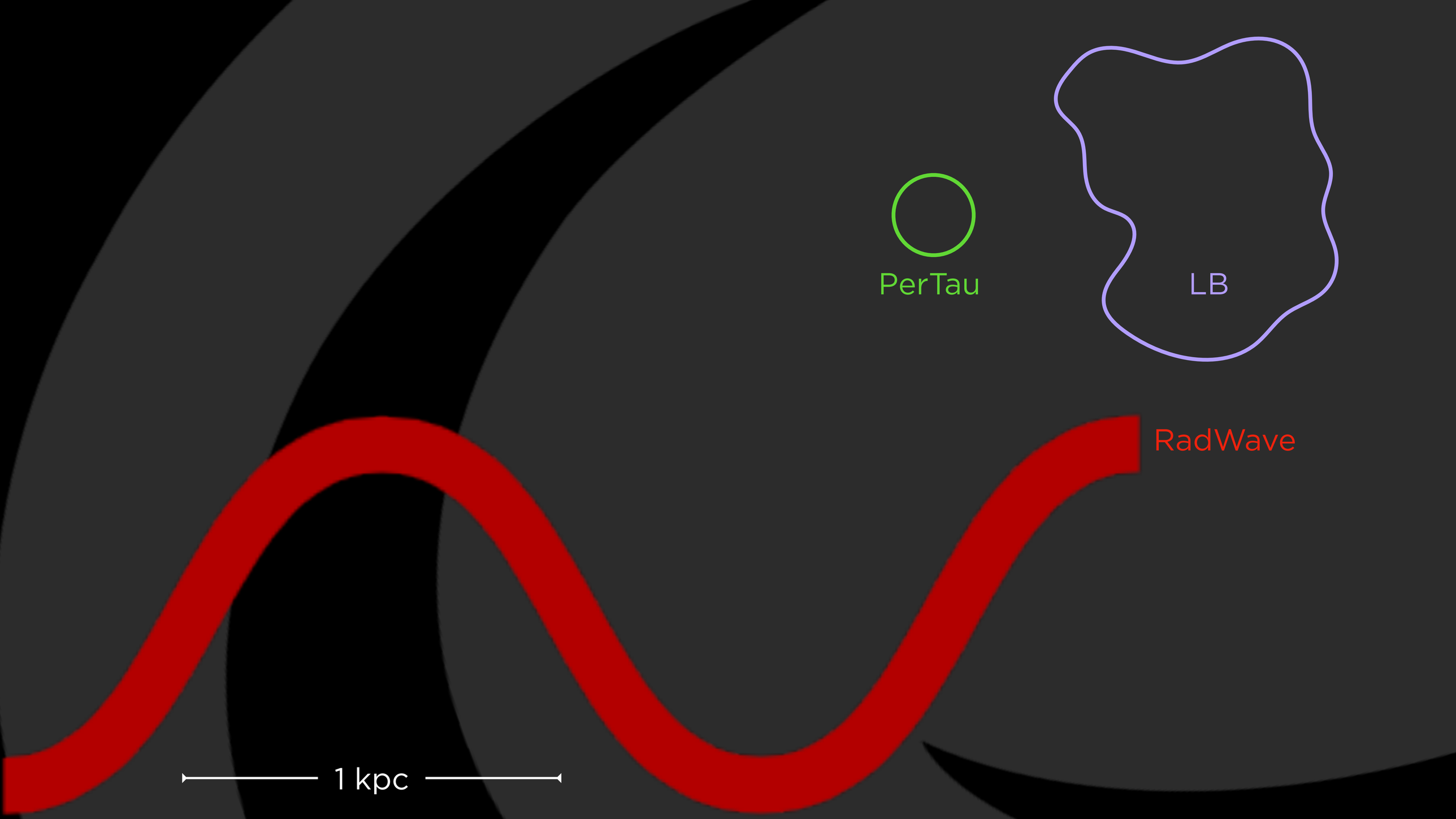
Join us, contribute, and yes, you get a T-Shirt.

2 MilkyWay3D.org founders wearing the colors (grad student Theo O’Neill & AMNH’s Dr. Jackie Faherty, at the Flatiron Insitute, NYC, Fall 2023

2010 2014 2015 2018 2020 2024 2021 2022 2024 2022

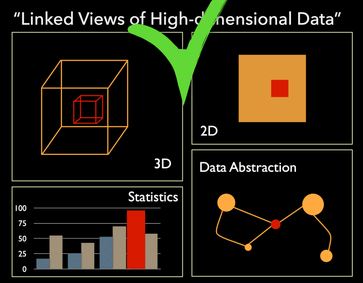
Nessie Bones Skeleton Perseus RadWave PerTau LB Barnard++


PerTau
LB
RadWave
1 kpc

What's LIVE?

LIVE

Why Linked Views?



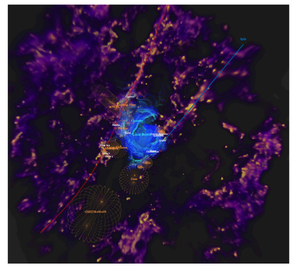
What's MilkyWay3D .org?

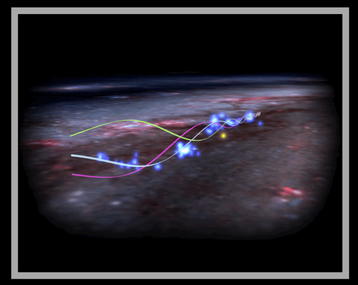
MILKYWAY3D.org

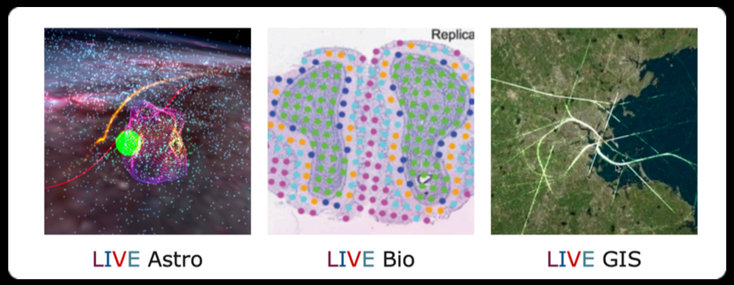
Why glue?

glue
multidimensional data exploration
glueviz.org

glue+3D dust maps= the "New" Milky Way







AR for Science and Outreach

glue→glupyter→LIVE-Astro, LIVE-Bio, LIVE-GIS

2020 The Radcliffe Wave

presented by Alyssa Goodman,
Center for Astrophysics | Harvard & Smithsonian,
Radcliffe Institute for Advanced Study

Nature paper by: João Alves[1,3], Catherine Zucker[2], Alyssa Goodman[2,3],
Joshua Speagle[2], Stefan Meingast[1], Thomas Robitaille[4],
Douglas Finkbeiner[3], Edward Schlafly[5] & Gregory Green[6]

representing
(1) University of Vienna; (2) Harvard University;
(3) Radcliffe Insitute; (4) Aperio Software;
(5) Lawrence Berkeley National Laboratory;
(6) Kavli Insitute for Particle Physics and Cosmology

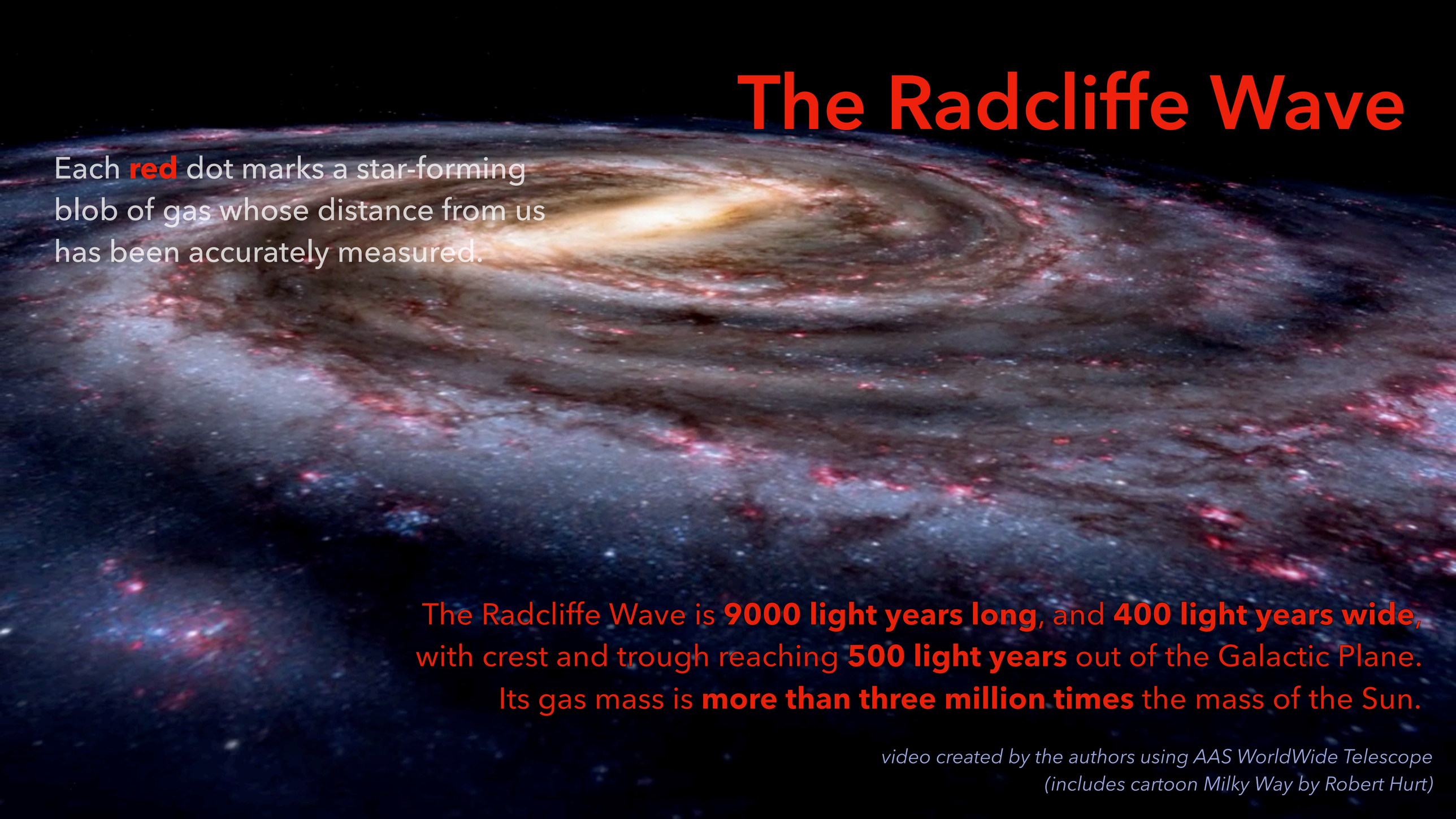
The Radcliffe Wave

CARTOON*

DATA

*drawn by Dr. Robert Hurt, in collaboration with Milky Way experts based on data; as shown in screenshot from AAS WorldWide Telescope

The Radcliffe Wave



Each **red** dot marks a star-forming blob of gas whose distance from us has been accurately measured.

The Radcliffe Wave is **9000 light years long**, and **400 light years wide**, with crest and trough reaching **500 light years** out of the Galactic Plane. Its gas mass is **more than three million times** the mass of the Sun.

video created by the authors using AAS WorldWide Telescope (includes cartoon Milky Way by Robert Hurt)

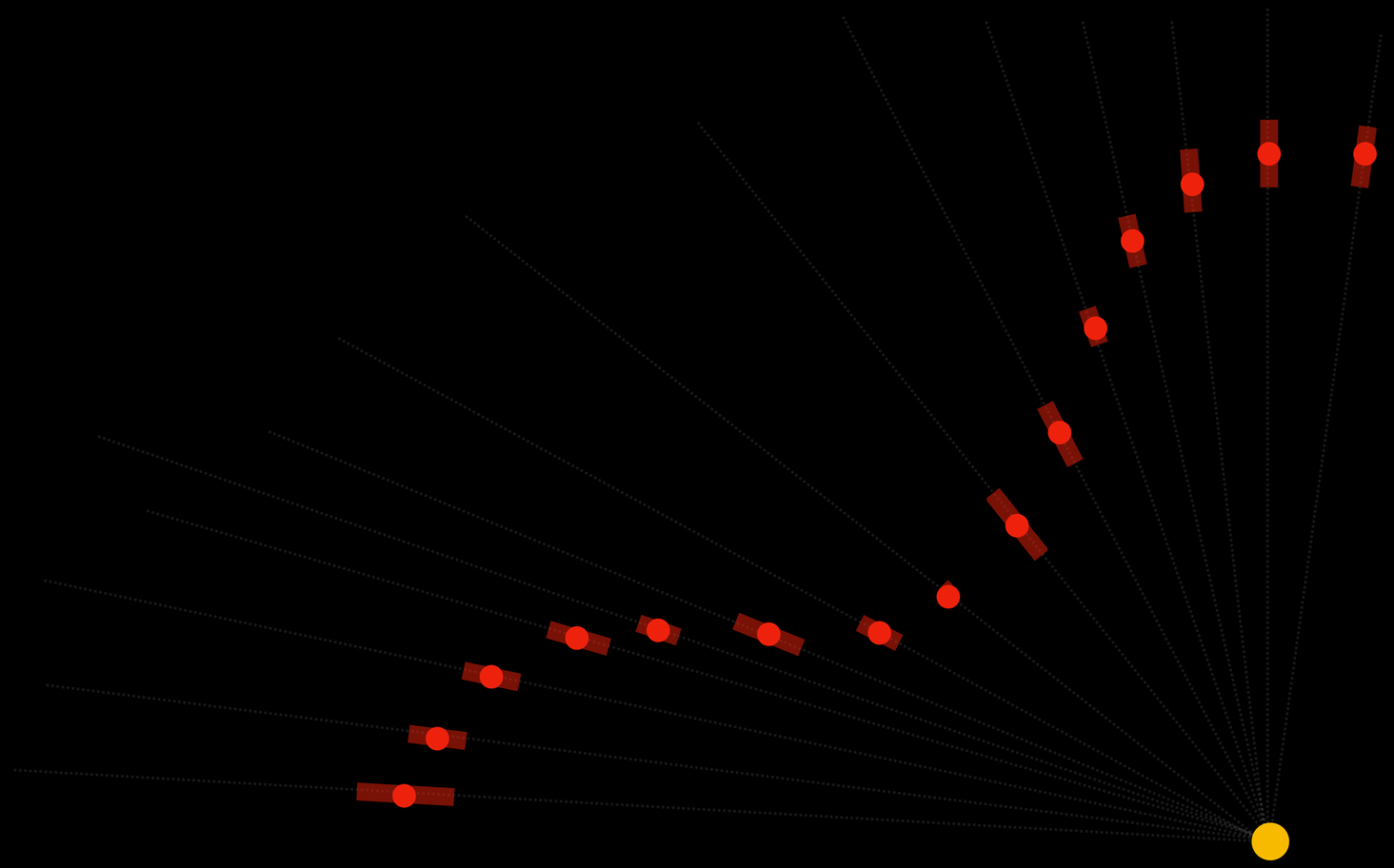
DISTANCES!!

We can now measure distances to gas clouds in our own Milky Way galaxy to ~5% accuracy.

Uncertain Distances

SCHEMATIC CARTOON(!)

Distances estimates **BEFORE** 3D dust mapping & Gaia (~30%)



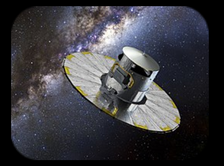
"The Radcliffe Wave"

SCHEMATIC CARTOON(!)

Distances estimates **AFTER** 3D dust mapping & Gaia (~5%)

HOW= 3D dust mapping*

+ Gaia*

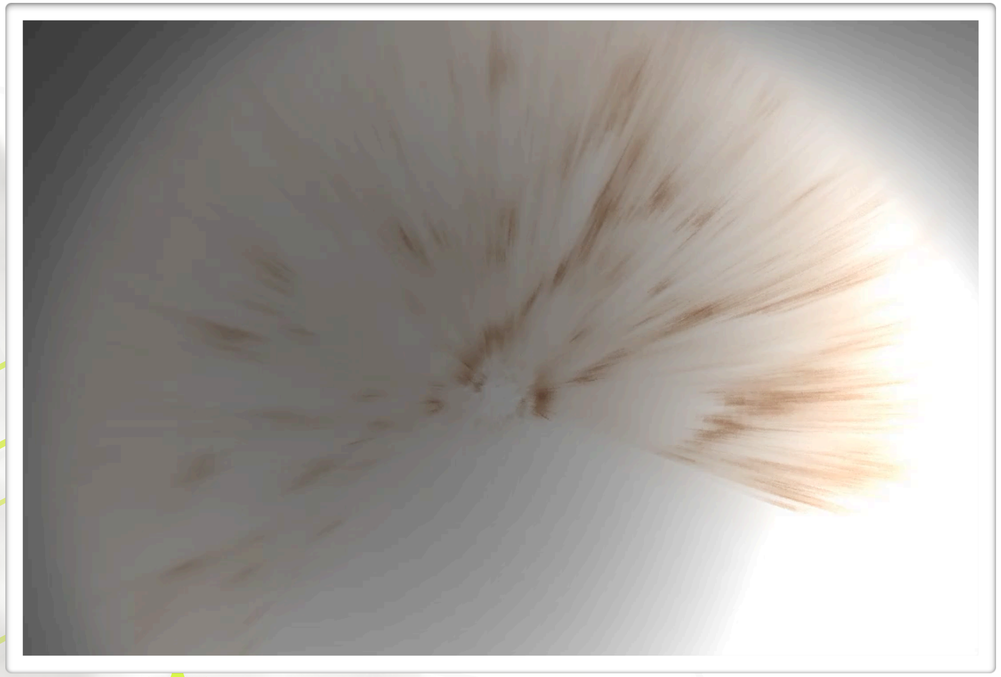


+ glue*

+ WorldWide Telescope

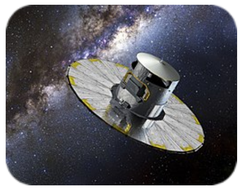
*2 million CPU hours, Harvard *800 million stars, ESA *NASA/JWST, NSF *Microsoft Research, NSF, AAS

Extinction & Reddening, from Color Imaging



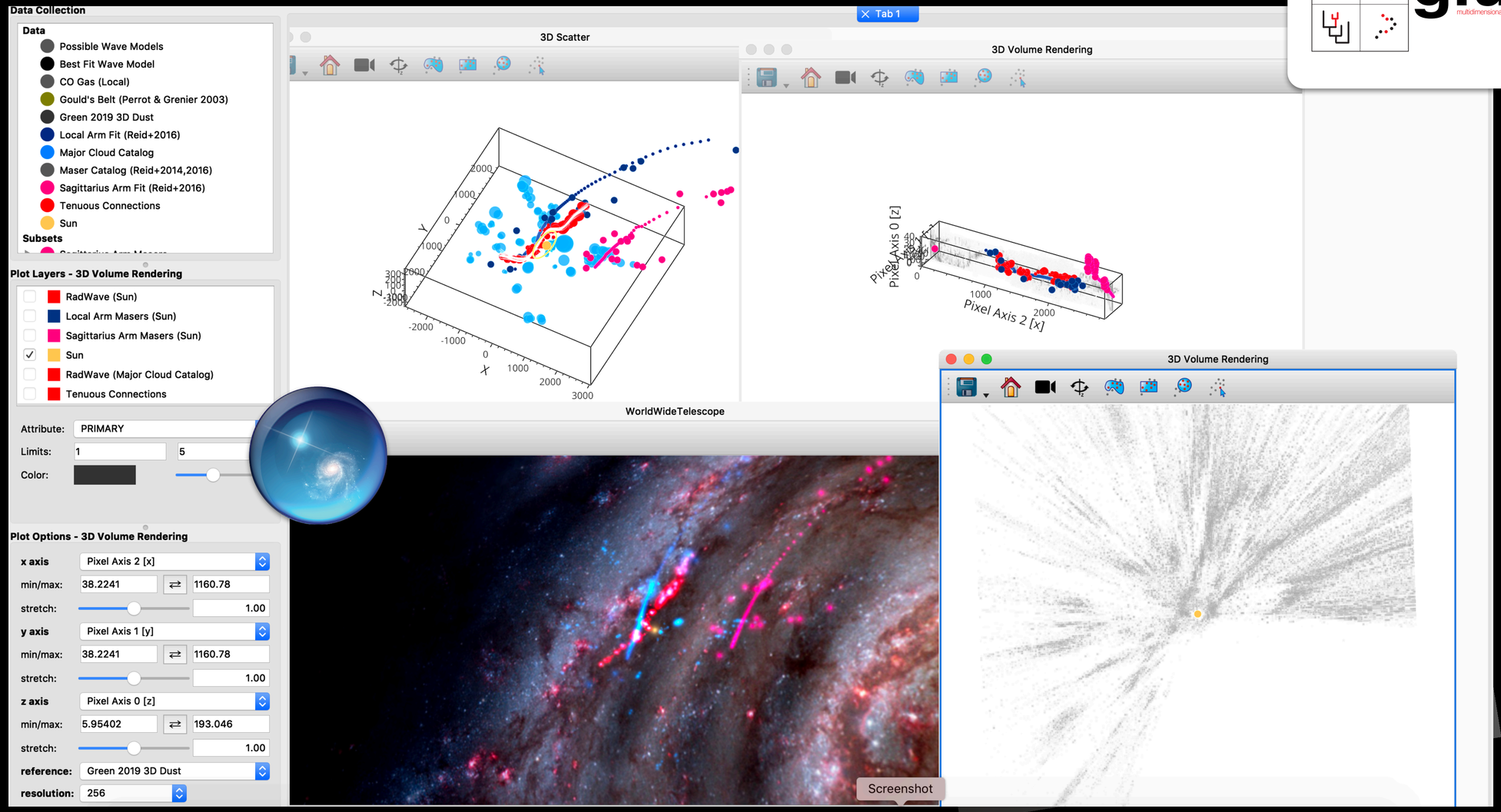
Green et al. 2019

Can infer matter's distance from *dust's* effects on stars.



WARNING: schematic diagram, NOT to scale (credit A. Goodman, 2019)

“Seeing” The Radcliffe Wave, in 3D

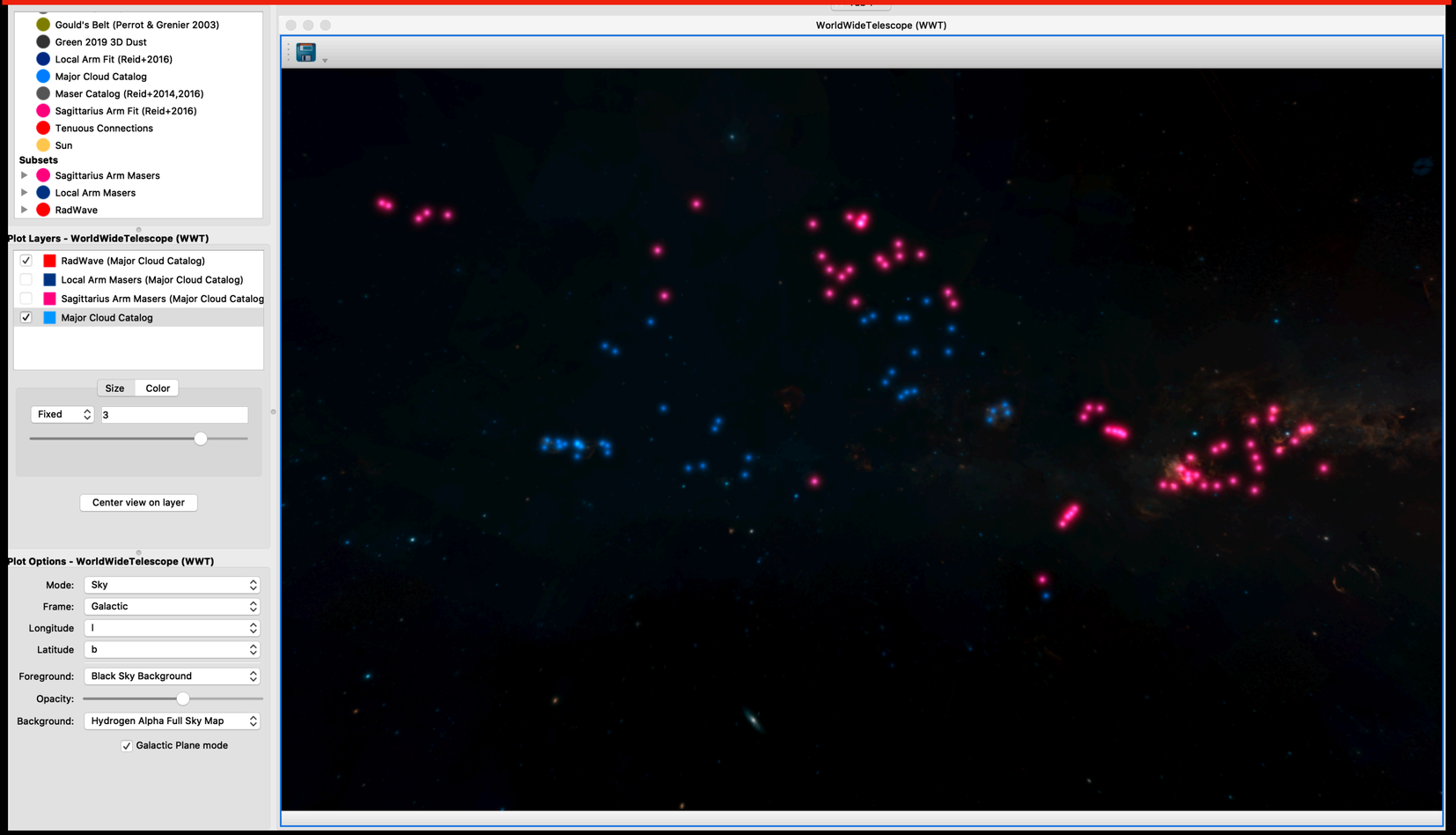


AAS WorldWide Telescope: worldwidetelescope.org

glue: glueviz.org

WHY DIDN'T WE FIND THE RADCLIFFE WAVE SOONER?

It's not apparent in 2D on the Sky.



AAS WorldWide Telescope: worldwidetelescope.org glue: glueviz.org

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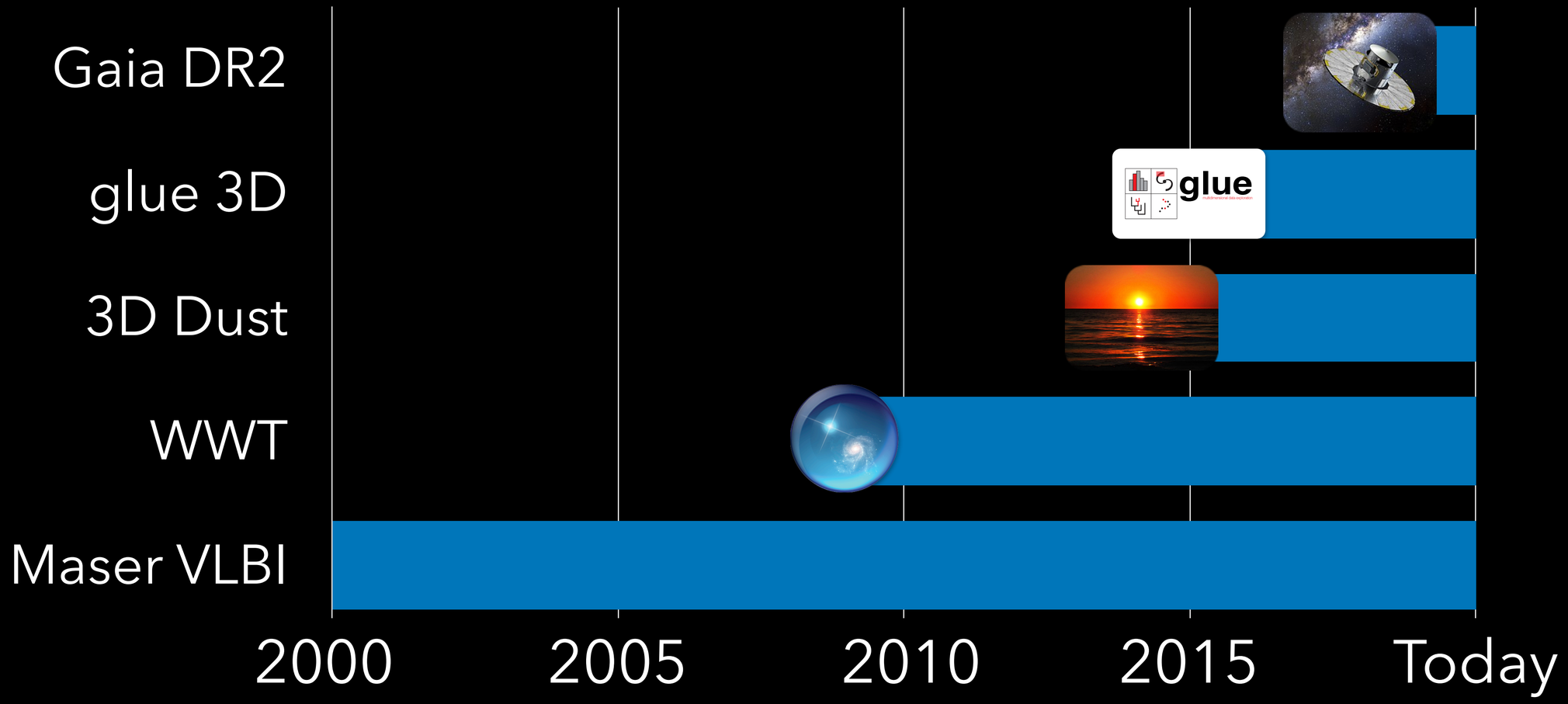
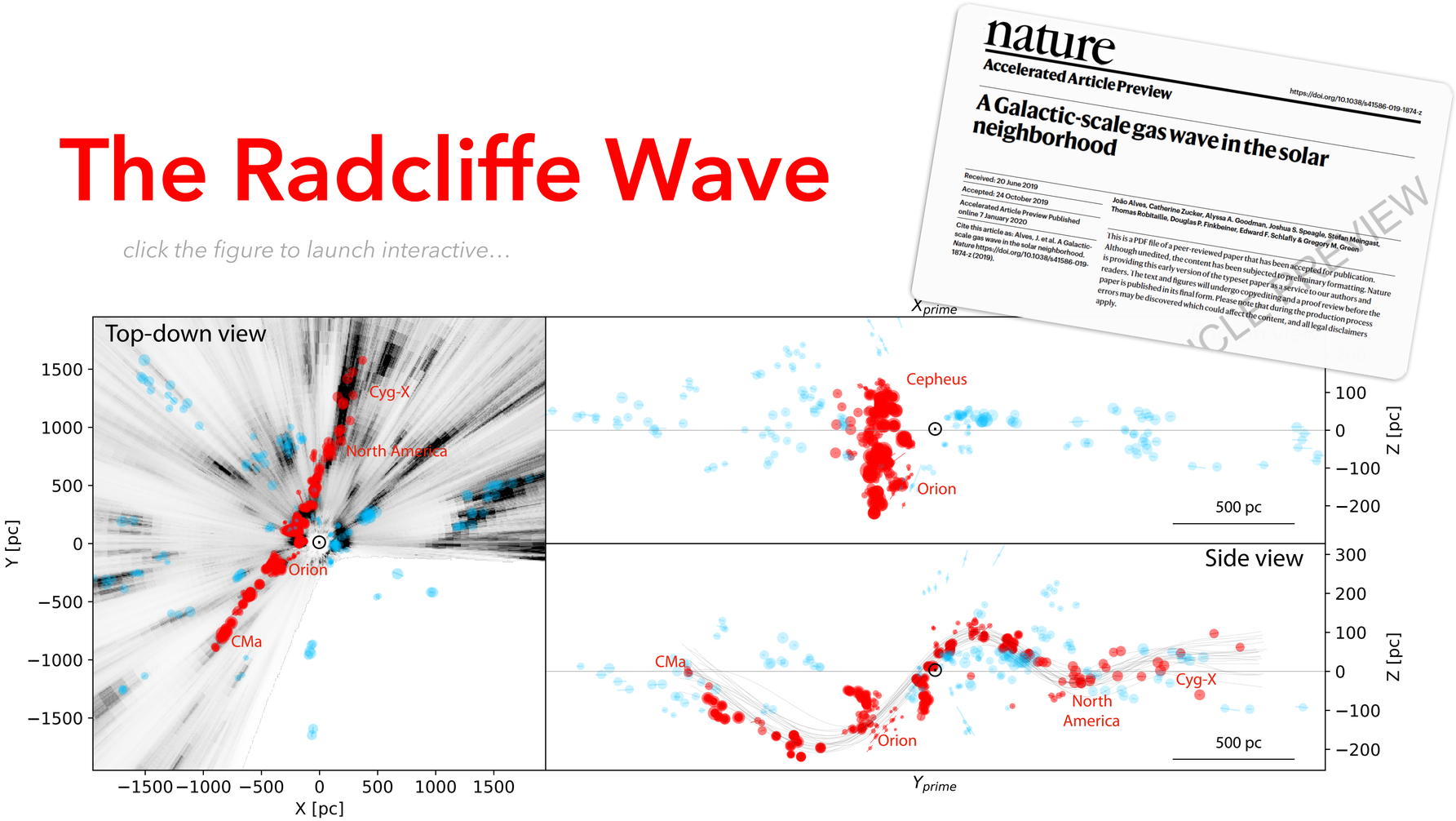


The Radcliffe Wave

click the figure to launch interactive…



RADWAVE

Surprising wave-like arrangement of star-forming gas *is* the "Local Arm" of the Milky Way.

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

Alves et al. *Nature* paper & two distance catalog papers by Zucker et al. (2019, 2020) include several interactive figures (via plot.ly & bokeh), and deep links to data (on Dataverse) and code (on GitHub) inspired by AAS "Paper of the Future" (Goodman et al. 2015)

RADWAVE

Surprising wave-like arrangement of star-forming gas *is* the “Local Arm” of the Milky Way.

“So What,” for Astronomers?

demise of “Gould's Belt”

end to 100-year-old paradigm

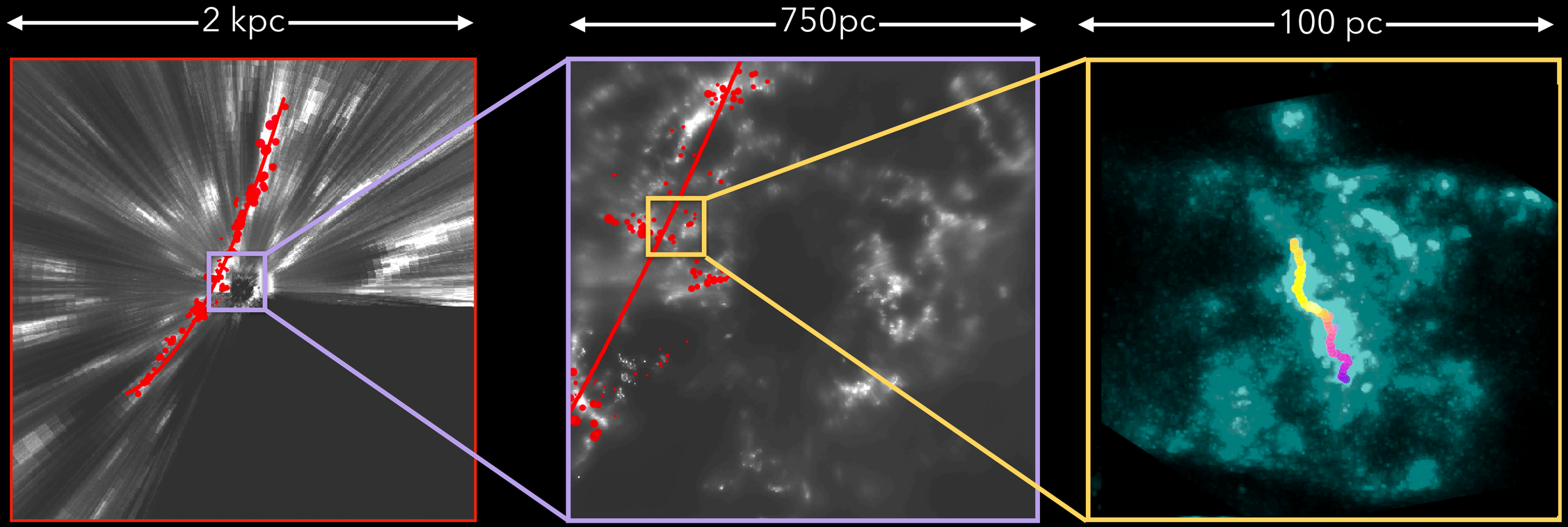
“Local Arm" not shaped as we thought it was, locally

arm is “straight" from top-down

big wave in “arm” never previously observed

wave’s origin unknown (collision? dark matter? accretion?)

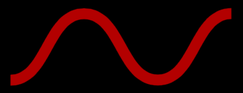
2019 to 2021: from distances to shapes

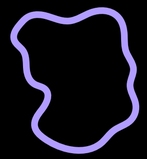


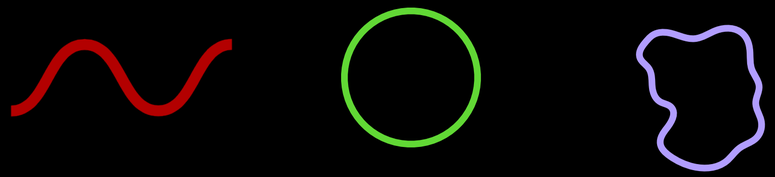
Zucker et al. 2020; Zucker & Speagle et al. 2019; Alves et al. 2020; Green et al. ***2019***

Leike, Glatzle, & Enßlin ***2020***

Zucker et al. ***2021****; Leike, Glatzle, & Enßlin 2020*







2020
2024

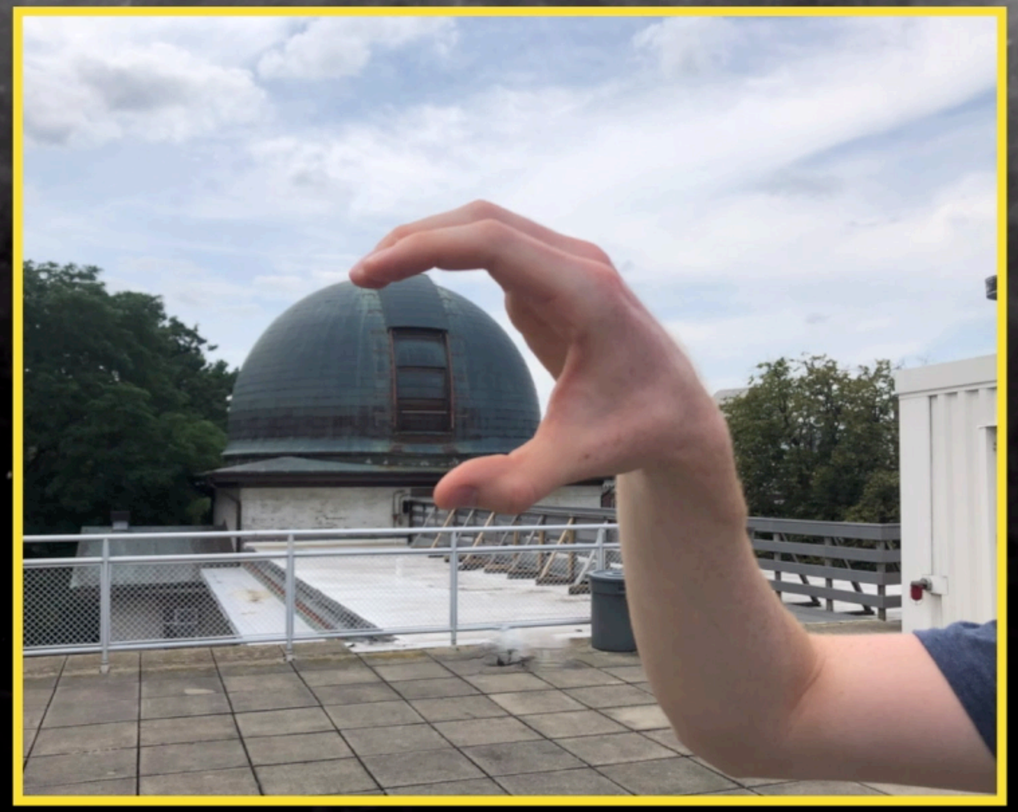
2021

2022
2024

2021

TAURUS

PERSEUS



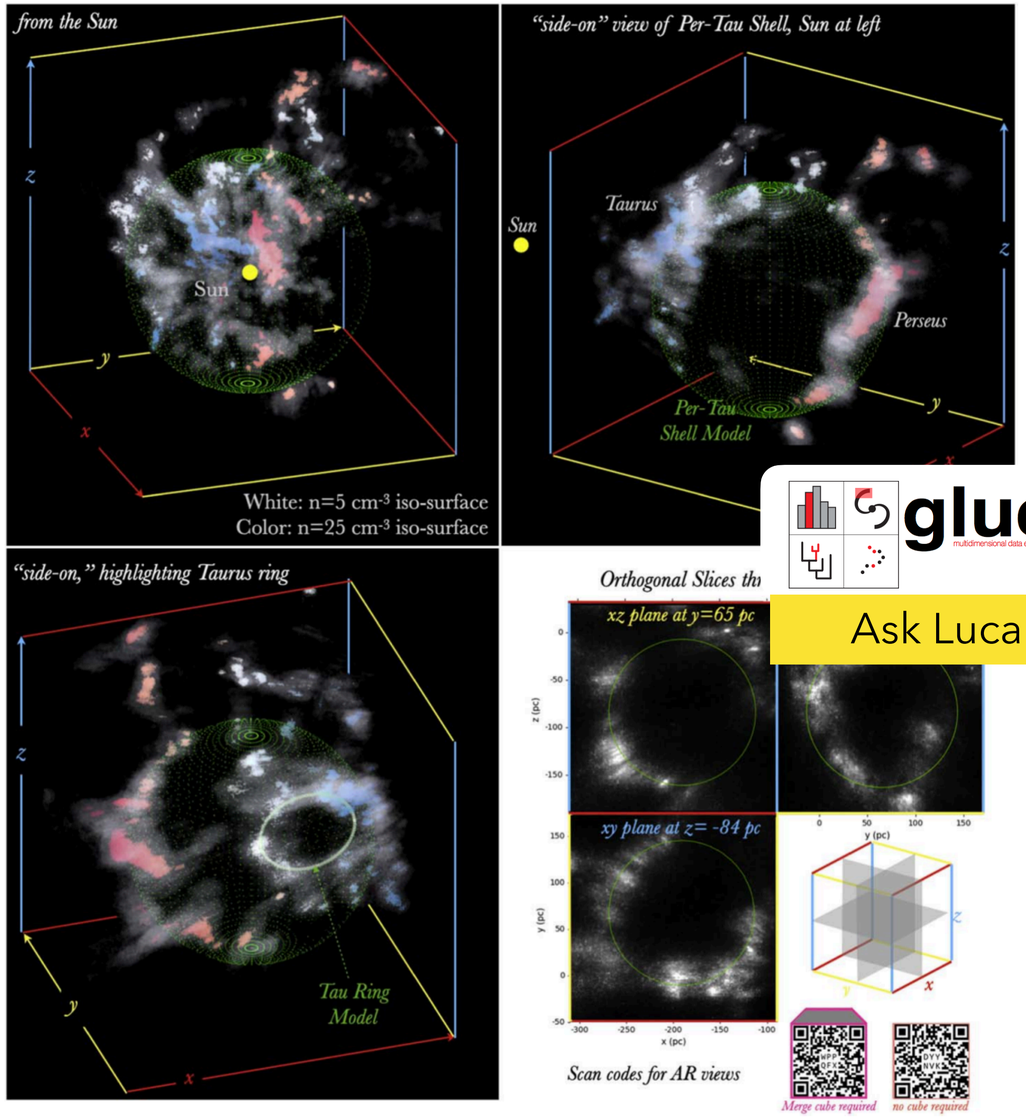


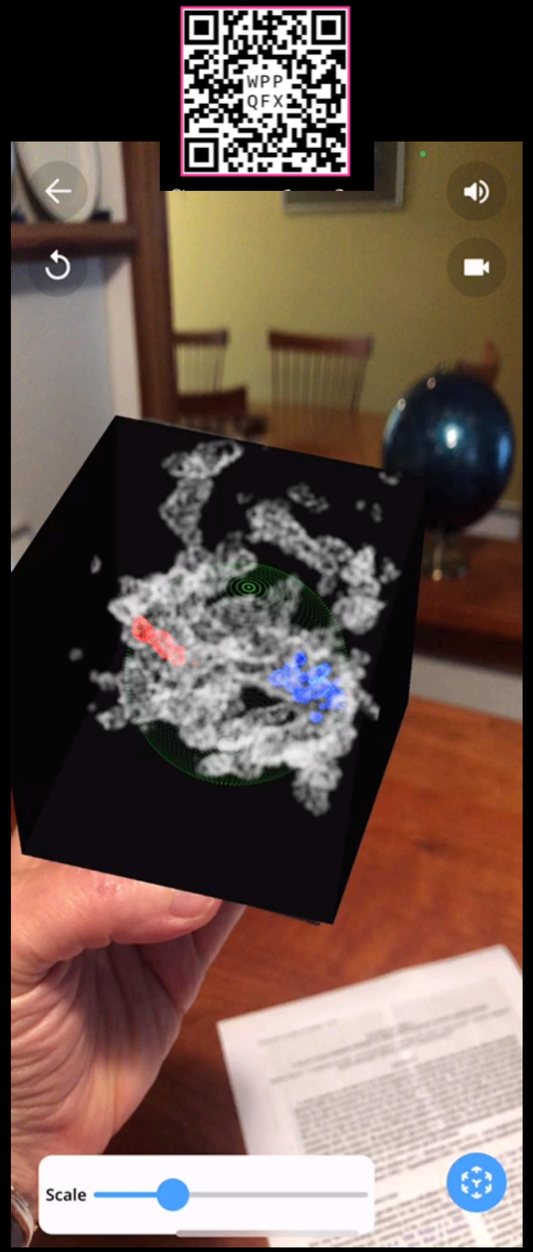
Figure 2. 3D views of the Per-Tau shell (for an interactive version[8] of this figure click here [9]; see Figure 5 for more static visualizations). Plotted are density iso-surfaces at levels $n = 5$ cm^{-3} (gray) and $n = 25$ cm^{-3} (color), overlaid with our spherical-shell model, radius $R_s = 78$ pc, distance from the Sun $d = 218$ pc. The $n = 25$ cm^{-3} surfaces are colored by distance from the Sun (blue-to-red). Top-left panel: view from the Sun (compare with Figure 1). Top-right panel: a side view of the region. Perseus and Taurus and their diffuse envelopes are arranged on two opposing sides of the Per-Tau shell. Bottom-left panel: another side view emphasizing the Tau Ring. The ellipse is the Tau Ring model (Appendix B). Bottom-right panel: 2D density slices along the *xy*, *xz*, *yz* planes. All planes intersect at shell's center. In all panels *xyz* are the Heliocentric Cartesian Galactic Coordinates.

2. *Tau Ring:* in a sky projection the Tau Ring is seen almost edge-on. The near side of the Tau Ring connects with the main body of Taurus at $d \approx 150$ pc, whereas the farthest part extends to $d \approx 220$ pc.

3. *The Fictitious Connection*: A filament seems to connect Taurus to Perseus. This connection is only a coincidental projection effect, where in actuality the filament is located at the distance of Taurus, and does not physically connect

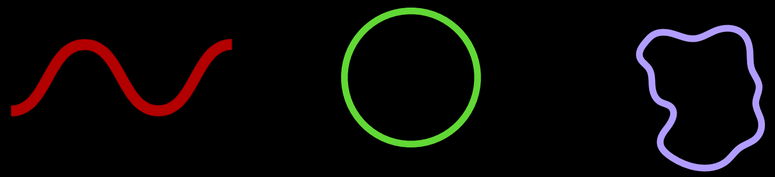
glue multidimensional data exploration → COSPACES

Ask Luca & Arzu for more info!



Bialy et al. 2021

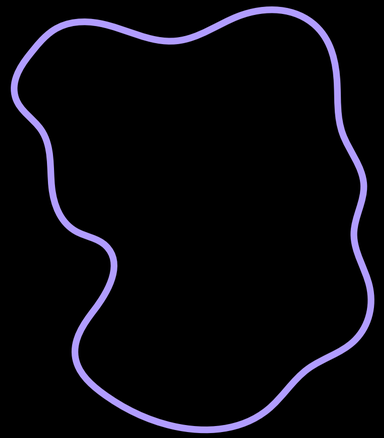
The Dataverse® Project



2020
2024

2021

2022
2024



2022

OUT THERE | DENNIS OVERBYE

Where Our Bubble Ends, Our Understanding Begins

By mapping a region devoid of gas and dust, scientists learn more about star formation.

JUST A BIT TOO LATE for New Year celebrations, astronomers have discovered that the Milky Way galaxy, our home, is, like champagne, full of bubbles.

As it happens, our solar system is passing through the center of one of these bubbles. Fourteen million years ago, according to the astronomers, a firecracker chain of supernova explosions drove off all the gas and dust from a region roughly 1,000 light-years wide, leaving it bereft of the material needed to produce new generations of stars.

As a result, all the baby stars in our neighborhood can be found stuck on the edges of this bubble. There, the staccato force of a previous generation of exploding stars has pushed gas clouds together into forms dense enough to collapse under their own ponderous if diffuse gravity and condense enough to ignite, as baby stars. Our sun, 4.5 billion years old, drifts through the middle of this space in a coterie of aged stars.

"This is really an origin story," Catherine Zucker said in a news release from the Harvard-Smithsonian Center for Astrophysics. "For the first time, we can explain how all nearby star formation began."

Dr. Zucker, now at the Space Telescope Science Institute in Baltimore, led a team that mapped what they call the Local Bubble in remarkable detail. They used data from a number of sources, particularly Gaia, a European spacecraft, that has mapped and measured more than a billion stars, to pinpoint the locations of gas and dust clouds.

Last year, a group of scientists led by João Alves, an astrophysicist at the University of Vienna announced the discovery of the Radcliffe Wave, an undulating string of dust and gas clouds 9,000 light-years long that might be the spine of our local arm of the galaxy. One section of the wave now appears to be part of our Local Bubble.

The same group of scientists published their latest findings in Nature, along with an elaborate animated map of the Local Bubble and its highlights.

The results, the astronomers write, provide "robust observational support" for a long-held theory that supernova explosions are important in triggering star formation, perhaps by jostling gas and dust clouds into collapsing and starting on the long road to thermonuclear luminosity.

Astronomers have long recognized the Local Bubble. What is new, said Alyssa Goodman, a member of the team also from the Harvard-Smithsonian Center for Astrophysics, is the observation that all local star-forming regions lie on the Local Bubble's surface. Researchers previously lacked the tools to map gas and dust clouds in three dimensions. "Thanks to 3-D dust-mapping, now we do," Dr. Goodman said.

According to the team's calculations, the Local Bubble began 14 million years ago with a massive supernova, the first of about 15; massive stars died and blew up. Their blast waves cleared out the region. There are now no stars younger than 14 million years in the bubble, Dr. Goodman said.

The bubble continues to grow at about 4 miles a second. "Still, more supernovae are expected to take place in the near future, like Antares, a red supergiant star near the edge of the bubble that could go any century now," Dr. Alves said. "So the Local Bubble is not 'done.'"

With a score of well-known star-forming regions sitting on the surface of the bubble, the next generation of stars is securely on tap.

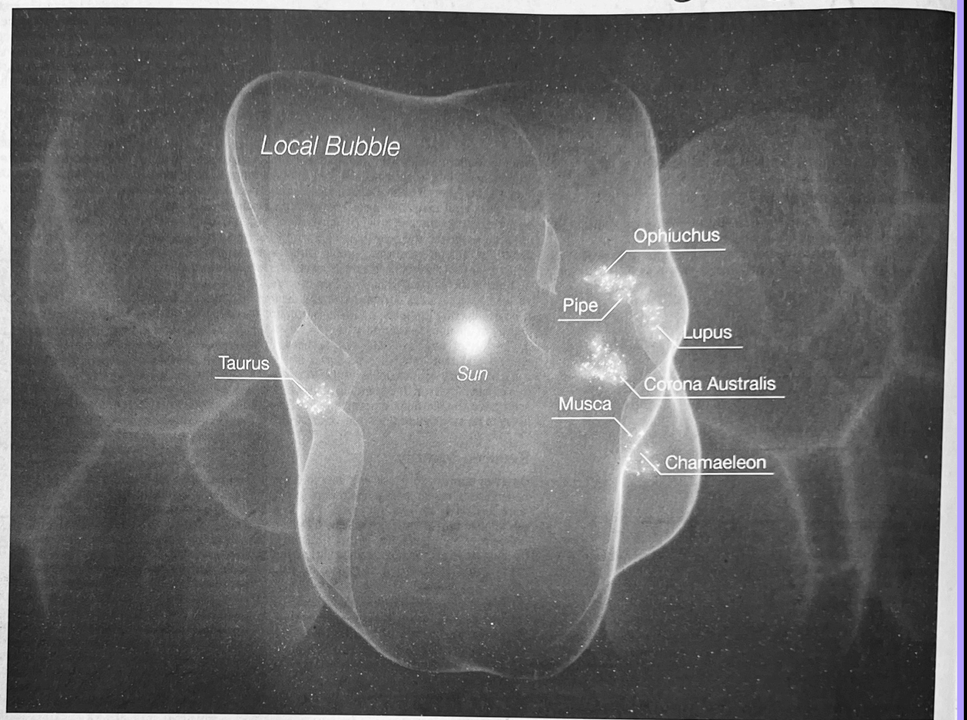
The team plans to go on and map more bubbles in the our Milky Way flute of champagne. There must be more, Dr. Goodman said, because it would be too much of a coincidence for the sun to be smack in the middle of the only one.

The sun's presence in this one is nonetheless coincidental, Dr. Alves said. Our star wandered into the region only five million years ago — long after most of the action — and will exit about five million years from now.

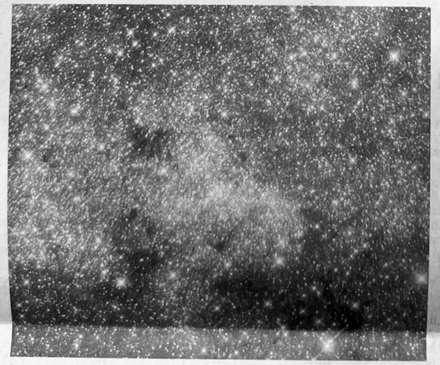
The motions of the stars are more irregular than commonly portrayed, as they are bumped gravitationally by other stars, clouds and the like, Dr. Alves said.

"The sun is moving at a significantly different velocity than the average of the stars and gas in the solar neighborhood," he noted. This would enable it to catch up and pass — or be passed by — the bubble.

"It was a revelation," Dr. Goodman said, "how kooky the sun's path really is compared with a simple circle."



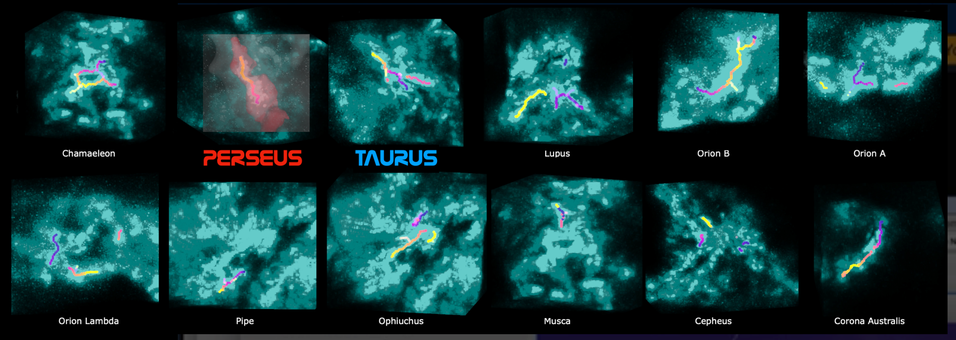
LEAH HUSTAK (STSCI)/CFA



NASA

Above, an illustration of the Local Bubble, which formed in the Milky Way, left, when supernova explosions drove off all the gas and dust from a 1,000-light-year-wide region.

The truth...



THE NEW YORK TIMES, TUESDAY, JANUARY 25, 2022

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Local Bubble
Ophiuchus
Pipe
Lupus
Taurus
Sun
Corona Australis
Musca
Chamaeleon

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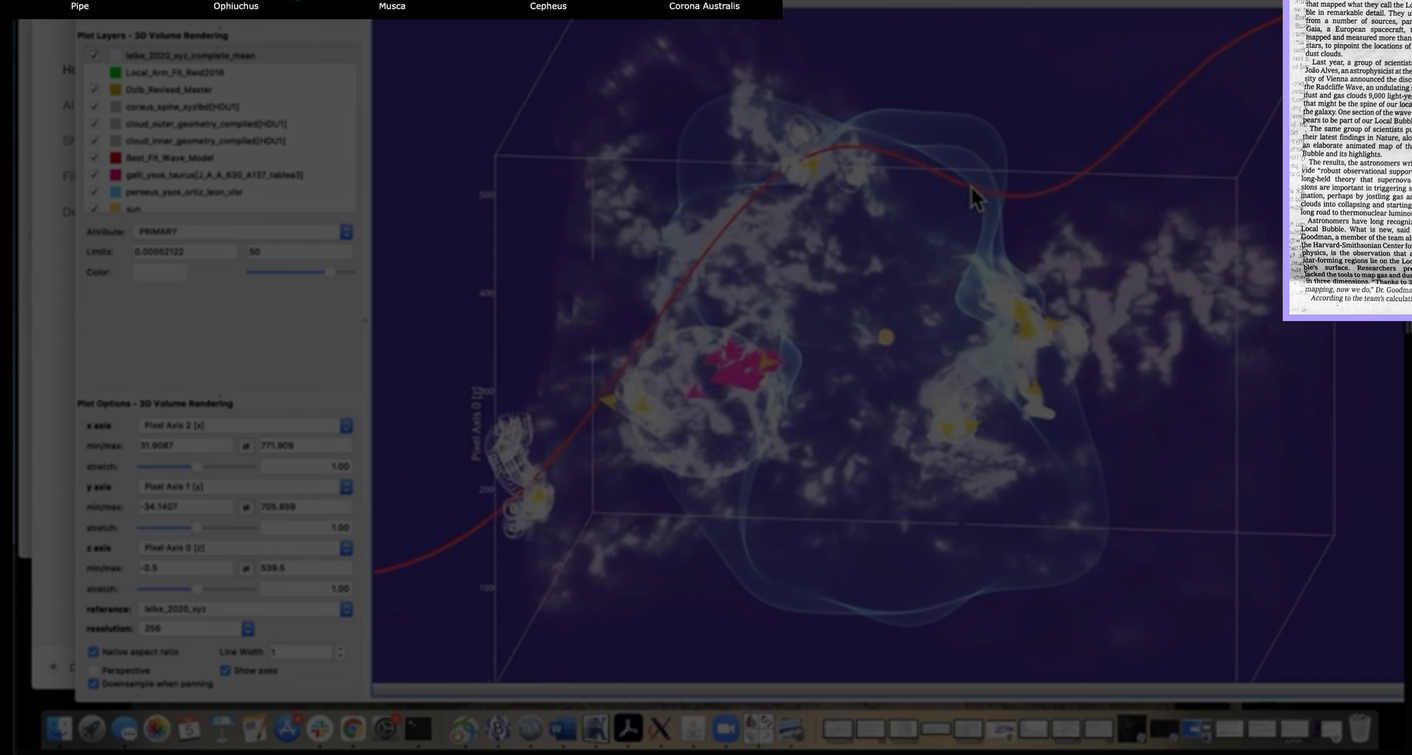
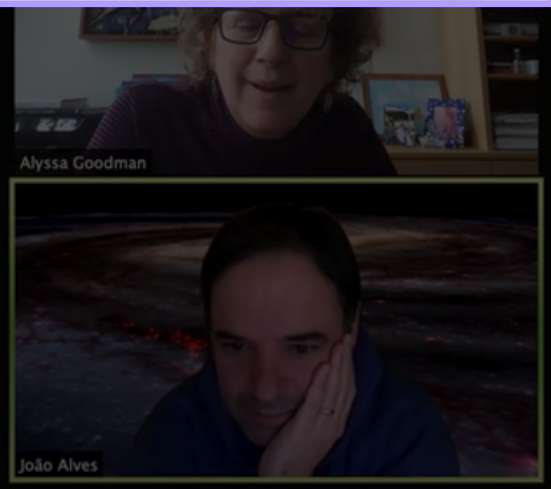
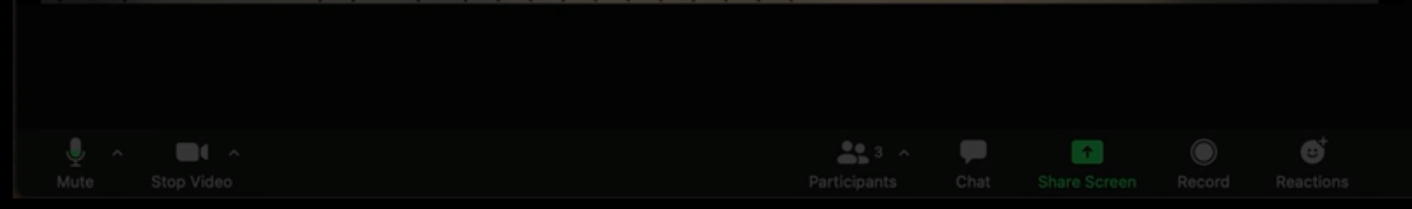
NASA

NYT, January 25, 2022







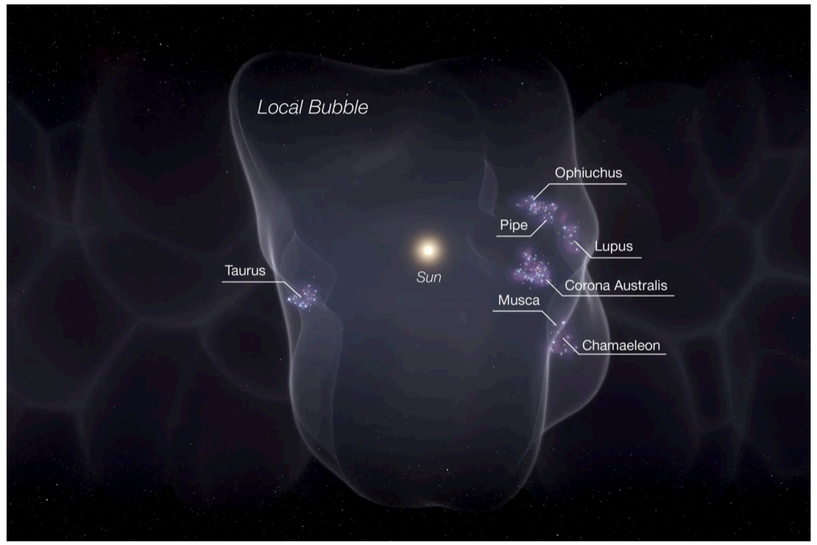
2022
LB

“An elaborate animated map”

– Dennis Overbye, *NY Times*

The New York Times

SCIENCE | A New Map of the Sun’s Local Bubble



An artist’s illustration of the Local Bubble with star formation occurring on the bubble’s surface. Leah Hustak (STScI)/Cfa

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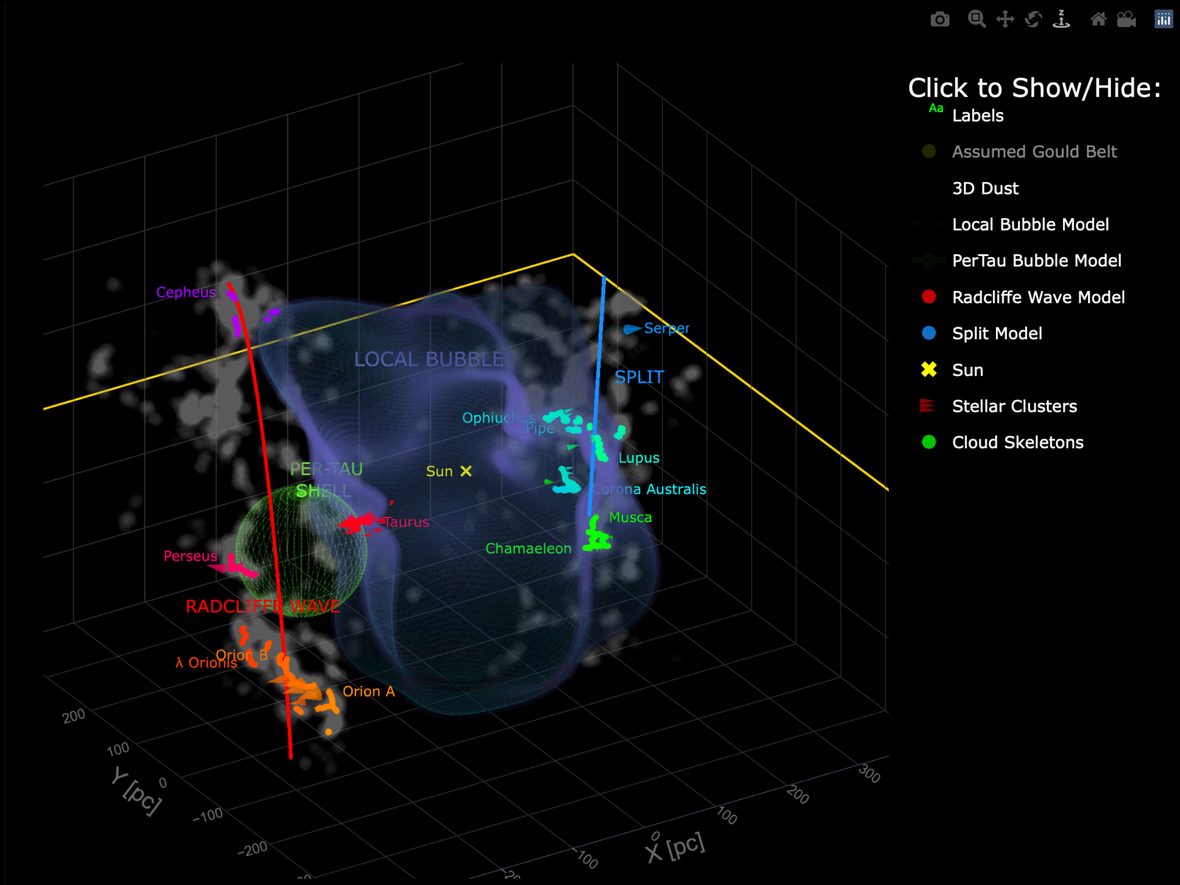
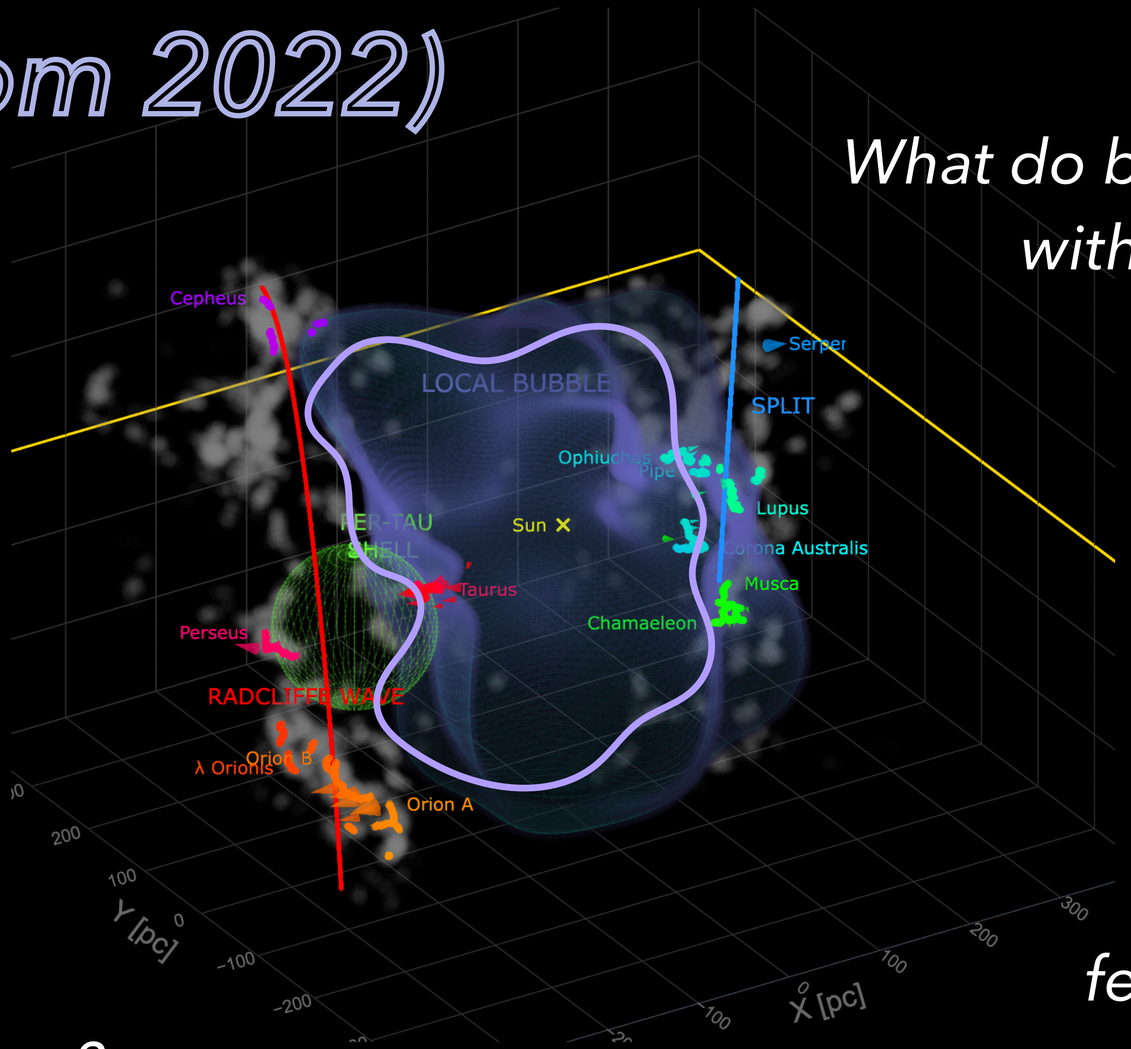


Figure 1, Zucker et al. 2022, *Nature*

–skipping 12 slides with the cool LB story–

"Next" *(from 2022)*

What do bubbles have to do with SPIRAL structure? Anything?



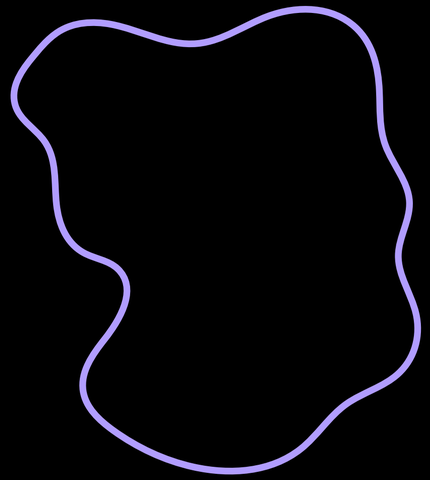
How do we SEARCH for other bubbles?

How do these bubbles INTERACT with each other?

Can observations now measure supernova feedback's effect on galaxy EVOLUTION?

[try the interactive figure]

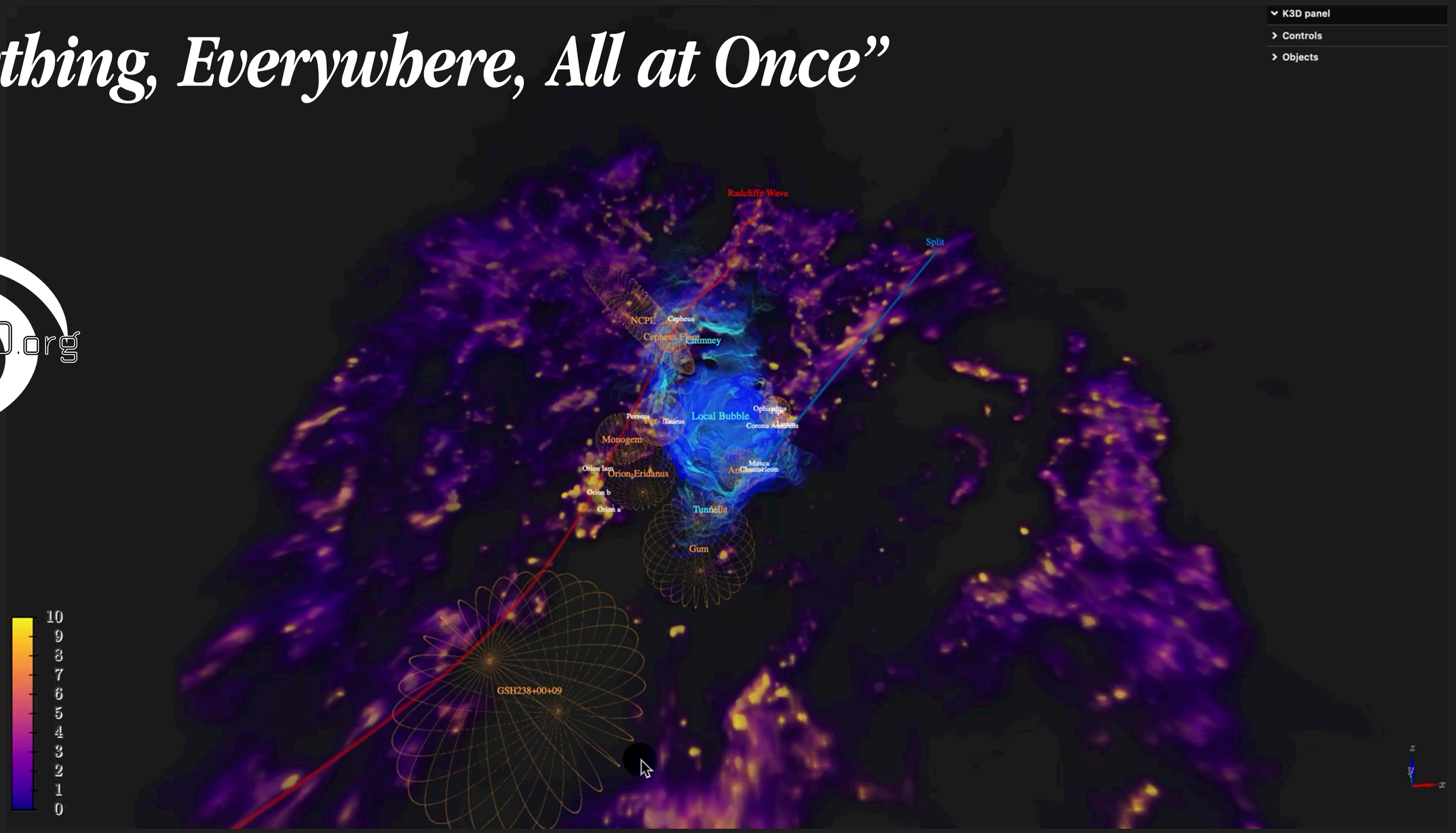
Local Bubble model [Pelgrims et al. 2020] , Superbubble expansion model [El-Badry et al. 2019], 3D Dust Maps [Leike et al. 2020, Lallement et al. 2019]



—skipping to last month—

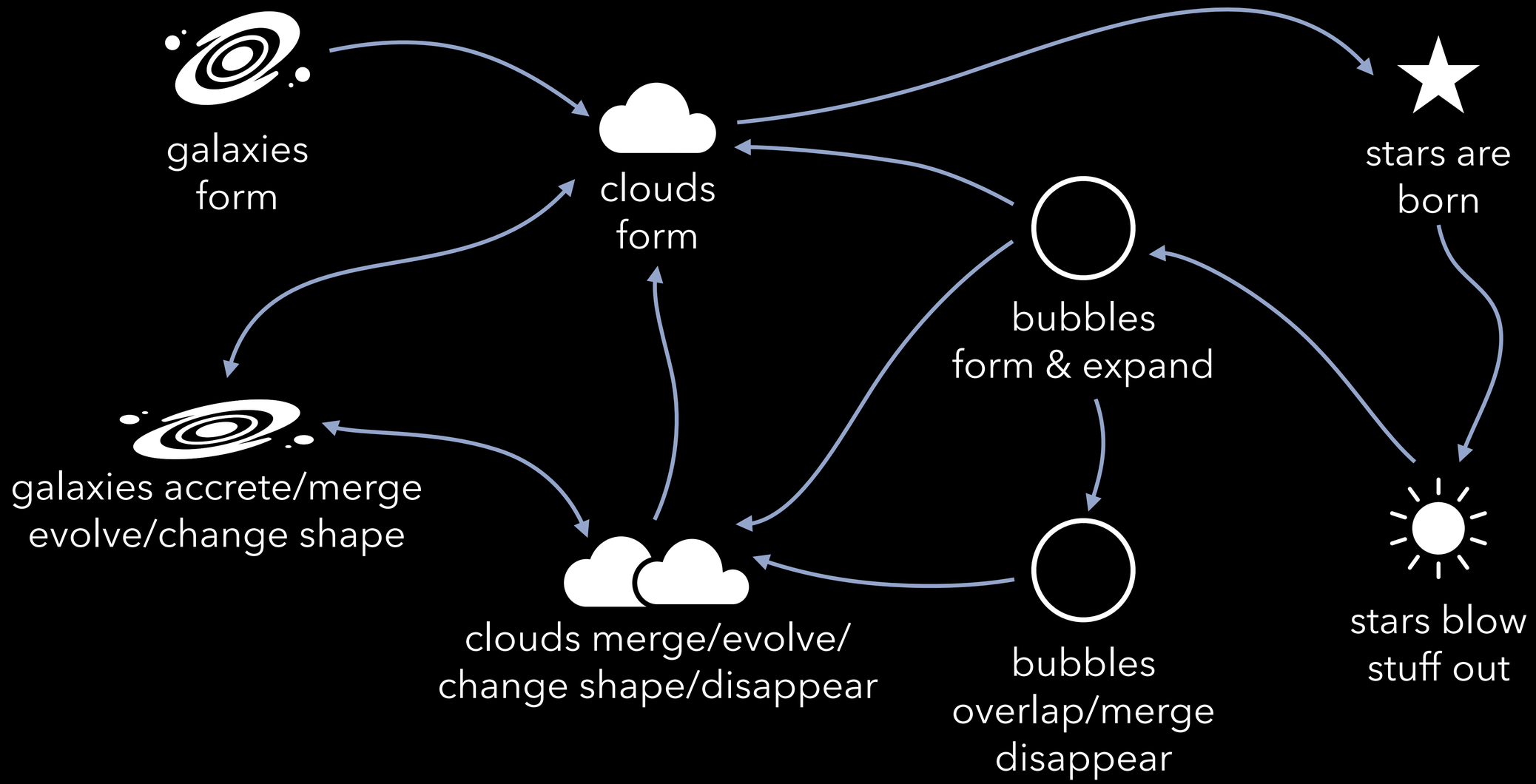
June
2024

“Everything, Everywhere, All at Once”

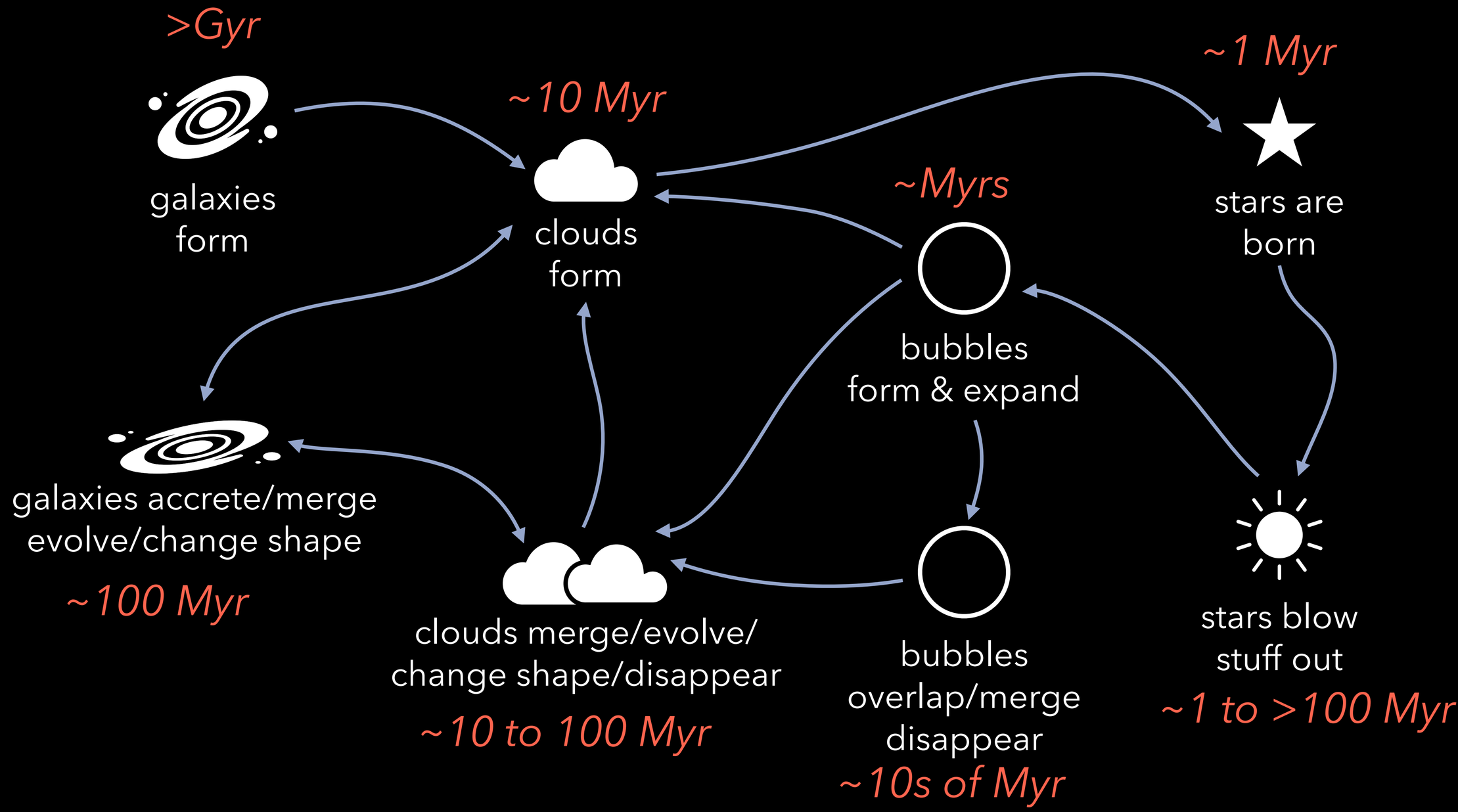


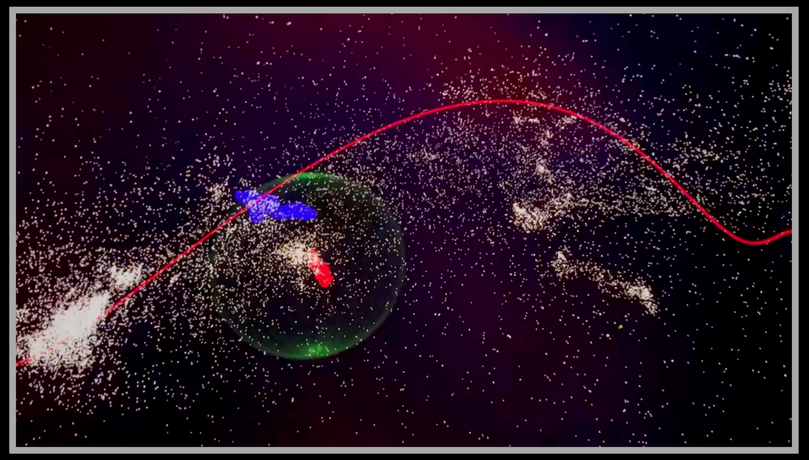
from O’Neill et al. 2024 “The Local Bubble is a Local Chimey"

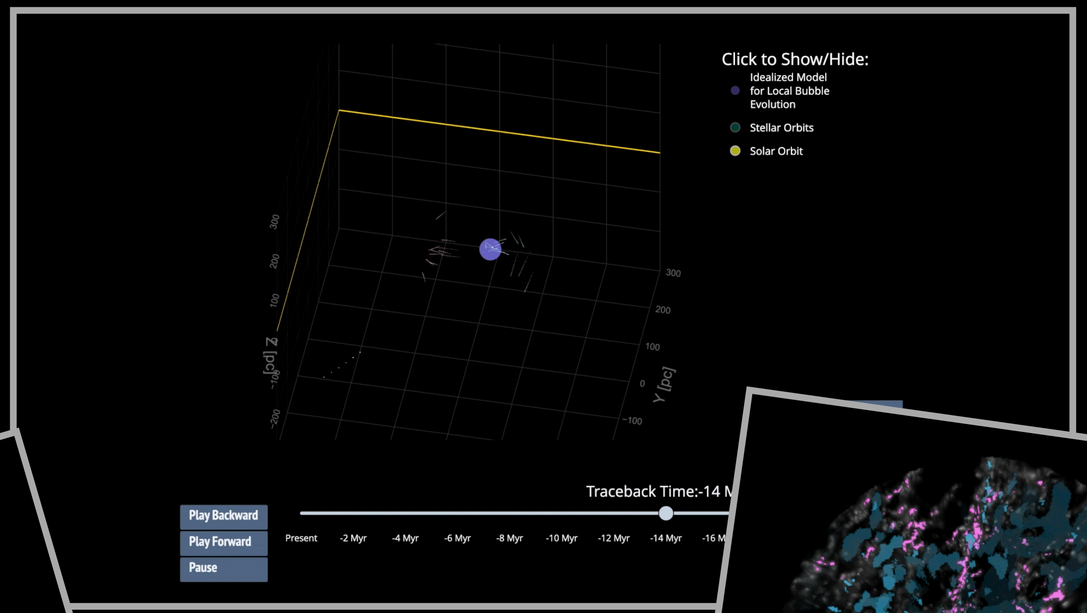
"Everything, Everywhere, All at Once"

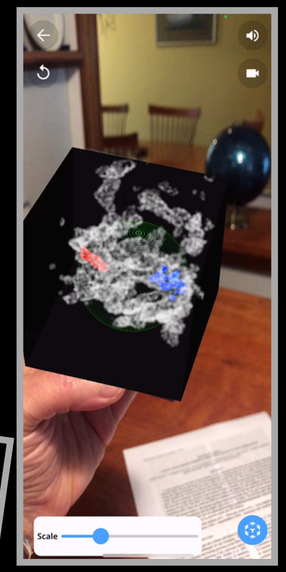


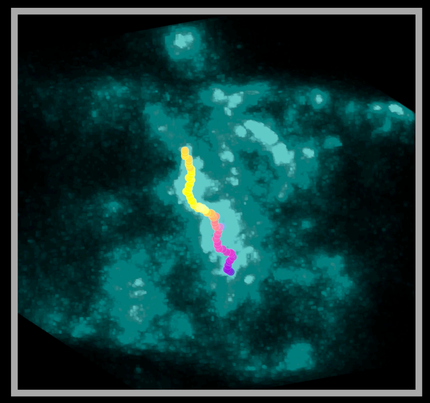
"Everything, Everywhere, All at Once"

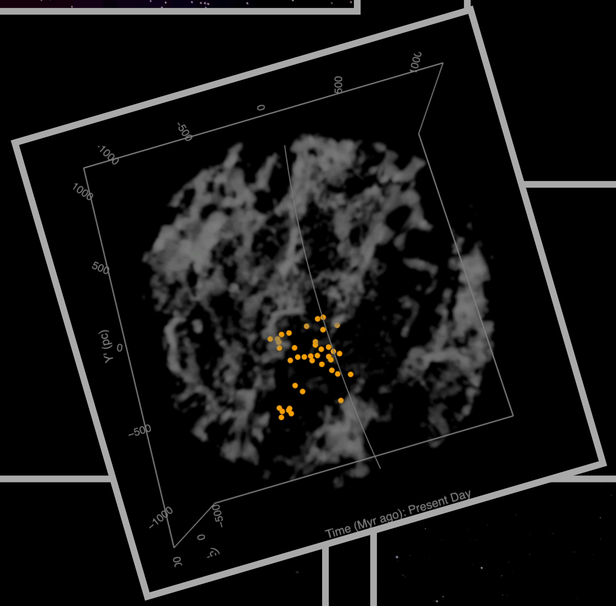


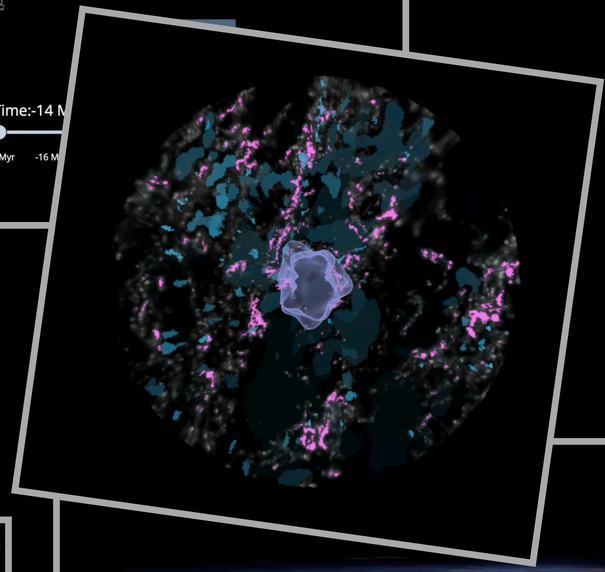




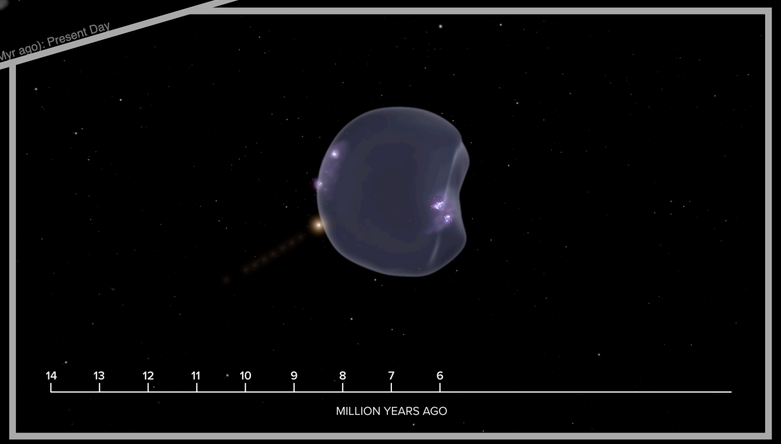


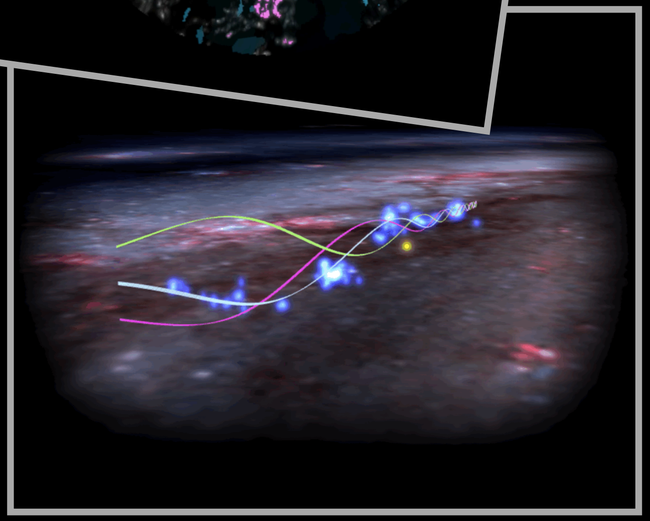






SO FAR





Zucker et al. 2021, Bialy et al. 2021; Zucker et al. 2022, Konietizka et al. 2024, O'Neill et al. 2024, Swiggum et al. 2024. *embargoed*

recent offspring of glue, including (way) beyond astronomy

2018 Jdaviz

2019 glue solutions inc.

2020 glupyter multidimensional data exploration

2021 glue genes

2021 CosmicDS

2021 SAVE

2021 glue-map

2024 LIVE-GIS TEMPO CosmicDS

2008 WORLDWIDE TELESCOPE

2012 glue multidimensional data exploration glueviz.org

2022 MILKYWAY3D.org

2023 LIVE

And there are *MANY* collaborators & supporters for all of these efforts!!!

Jdaviz 2018

glue solutions inc. 2019

glupyter multidimensional data exploration 2020

glue genes 2021

CosmicDS 2021 OpenSpace

SAVE glue-map 2021

LIVE-GIS TEMPO CosmicDS 2024

NASA

GORDON AND BETTY MOORE FOUNDATION NSF

NASA Google

NASA Smithsonian

Microsoft Research AAS NSF NASA

2008 2012

OpenSpace 2022

jupyter 2023

WORLDWIDE TELESCOPE

glue multidimensional data exploration glueviz.org

MILKYWAY3D.org

LIVE

LIVE

LIVE-env.org

LIVE Environments

About LIVE | Capabilities | Tech | Who are we? | Learn More

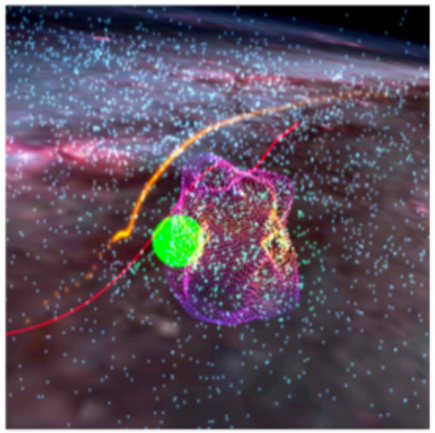
Linkable Interactive Visualization Exploration (LIVE) Environments

What is LIVE?

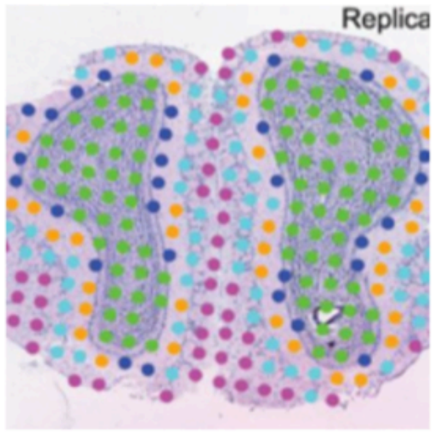
LIVE lets anyone build
"Linkable Interactive Visualization and Exploration" Environments.

LIVE is free, open-source, and helps with shared data and visualization challenges across astronomy (LIVE Astro), biology (LIVE Bio) and GIS (LIVE GIS).

As LIVE's infrastructure is being built, collaborators are ensuring its utility across Astronomy, Biology, and GIS by pursuing LIVE's science demonstration projects.



LIVE Astro



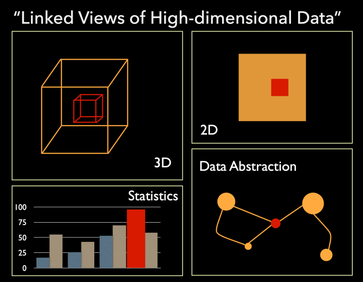
LIVE Bio

LIVE GIS

What's LIVE?

LIVE

Why Linked Views?



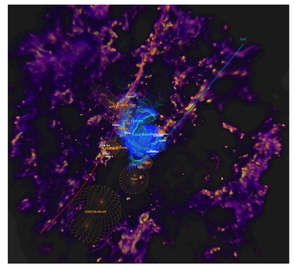
What's MilkyWay3D .org?

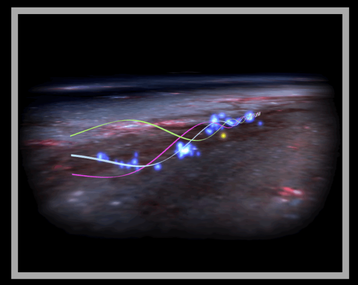
MILKYWAY3D.org

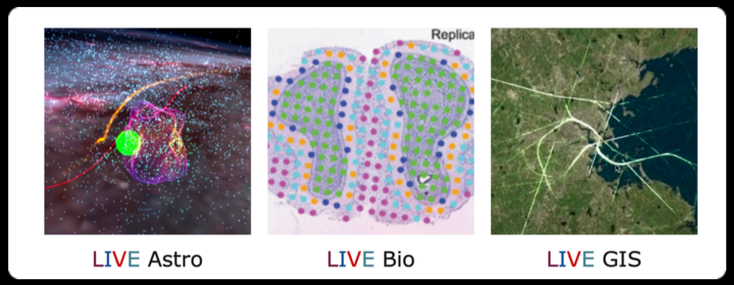
Why glue?

glue
multidimensional data exploration
glueviz.org

glue+3D dust maps= the "New" Milky Way

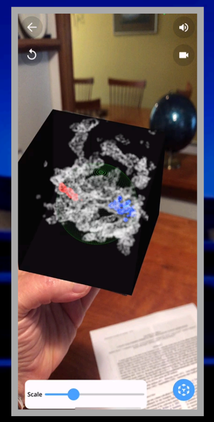


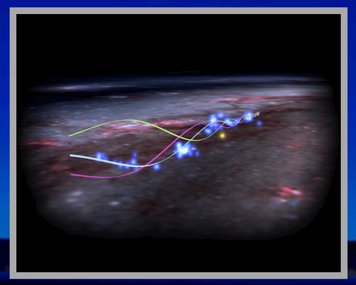


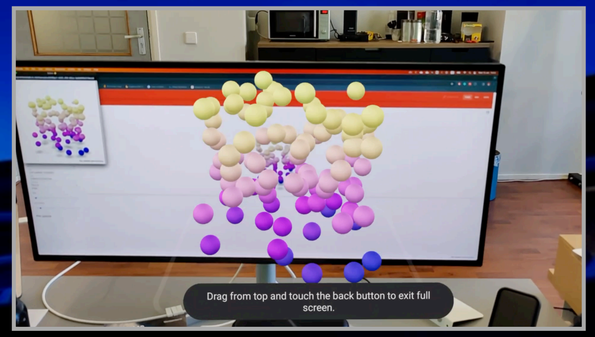


AR for Science and Outreach

glue→glupyter→LIVE-Astro, LIVE-Bio, LIVE-GIS

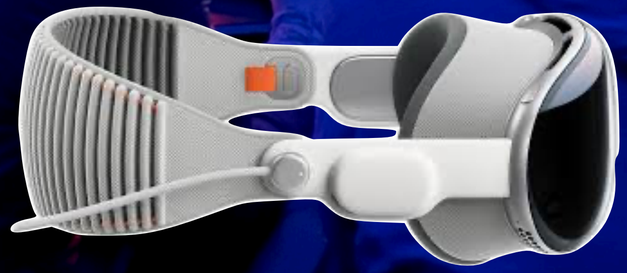




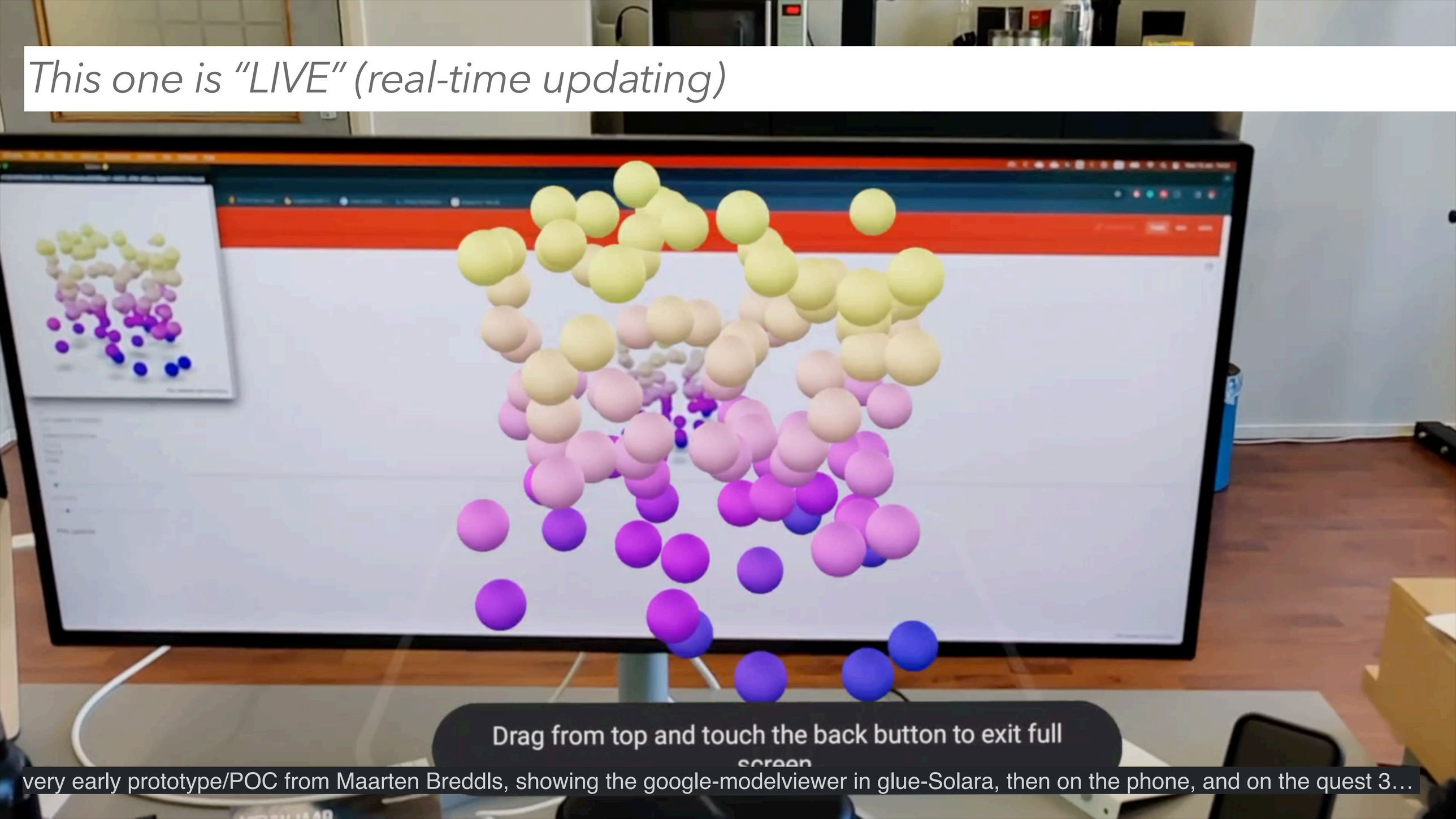


AR for Science and Outreach

What’s next for “LIVE” in AR?



This one is “LIVE” (real-time updating)

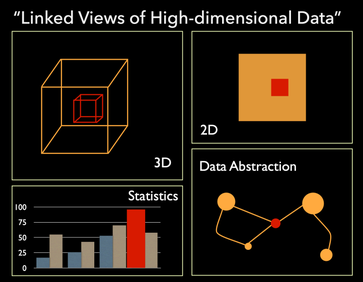


very early prototype/POC from Maarten Breddls, showing the google-modelviewer in glue-Solara, then on the phone, and on the quest 3…

What's LIVE?

LIVE

Why Linked Views?



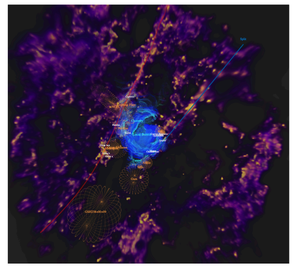
What's MilkyWay3D .org?

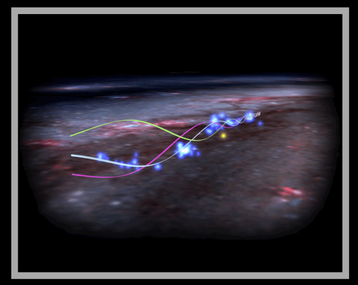
MILKYWAY3D.org

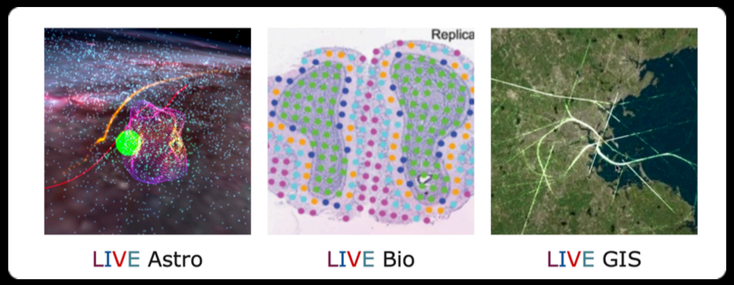
Why glue?

glue
multidimensional data exploration
glueviz.org

glue+3D dust maps= the "New" Milky Way







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