Our "PLAN"

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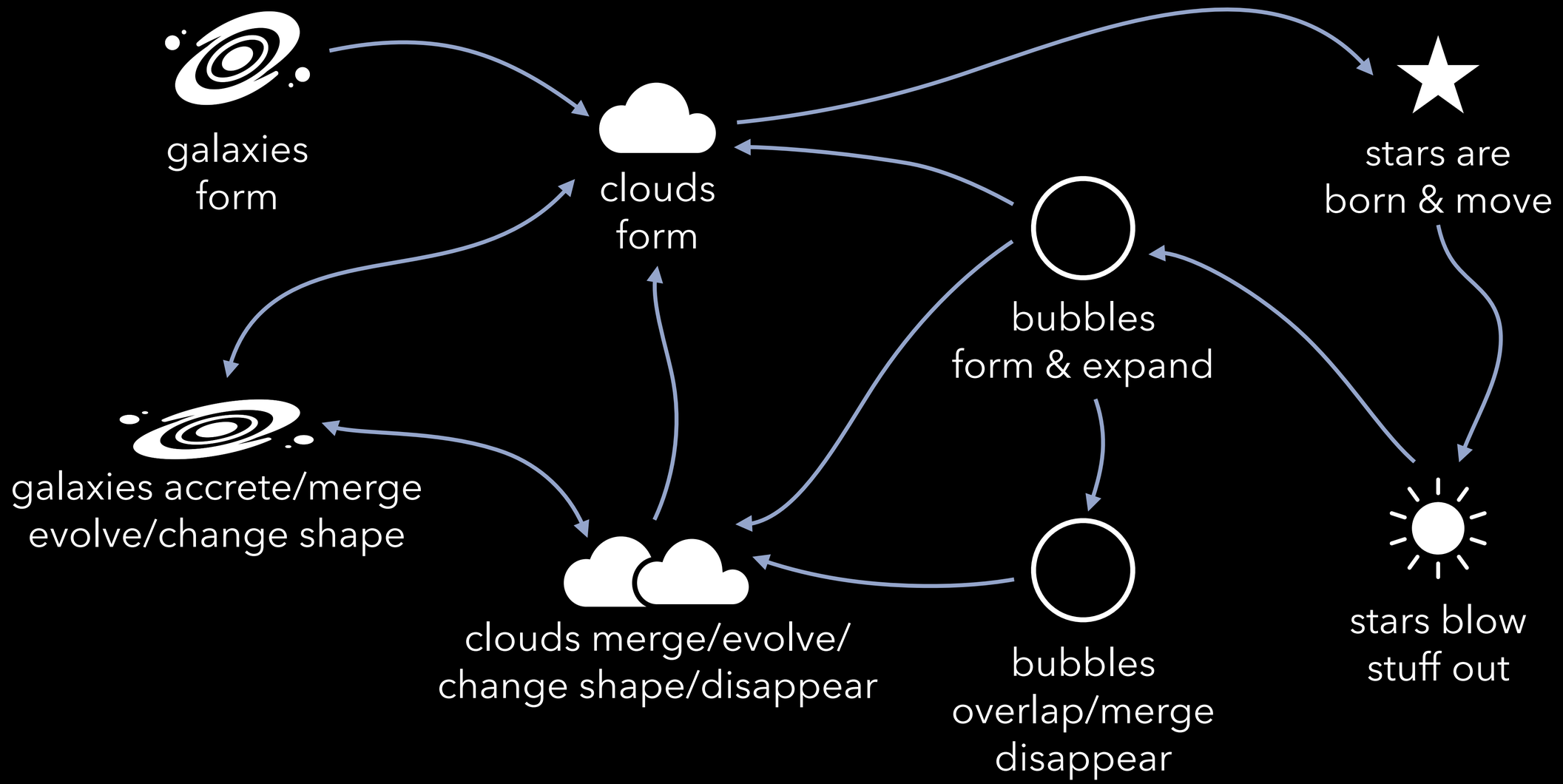
"Everything, Everywhere, All at Once"



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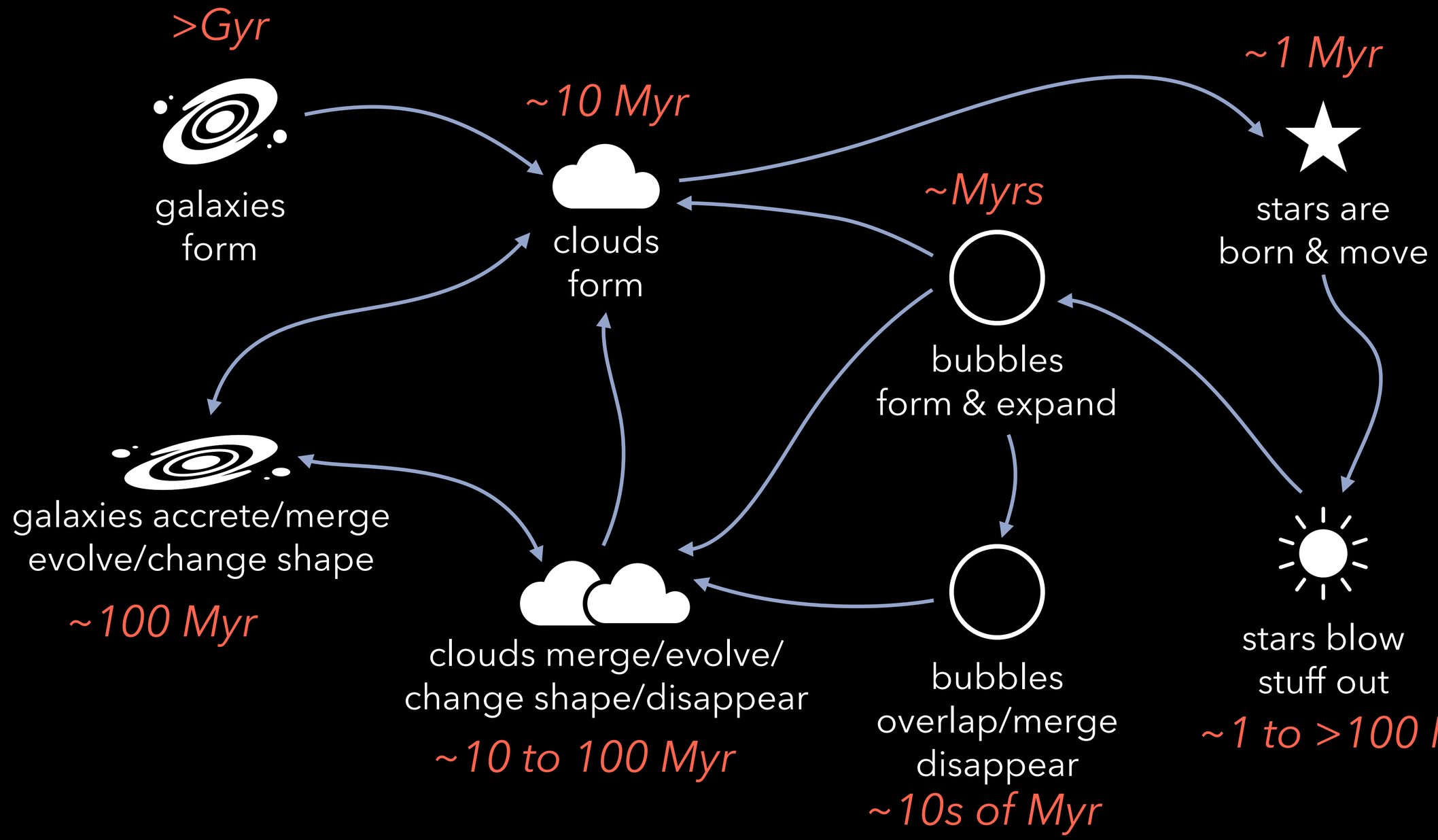


"Everything, Everywhere, All at Once"

MOVIE

1. molecular clouds "*form*"
2. new stars *form* in "molecular clouds"
3. stars *move* while and after they form
4. clouds "*evolve*" (grow, shrink, merge, change shape, change density) over time
5. winds & explosions from stars (called "feedback") *cause* some of the clouds' evolution
6. the most "significant" feedback events can *cause* new molecular clouds to form (see #1!)

Nothing stays still. Nothing lasts forever.

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

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

glue

AMERICAN ASTRONOMICAL SOCIETY WORLDWIDE TELESCOPE

OpenSpace

linking position and motion across dimensions,
using the plug-in architecture enabled by glue
(plug-ins include WorldWide Telescope, OpenSpace & more)

MAST

The Dataverse Project

DIGITAL universe

making data accessible online for decades

Lead: Alyssa Goodman, CfA

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

connecting real research data,
software, and science to learners

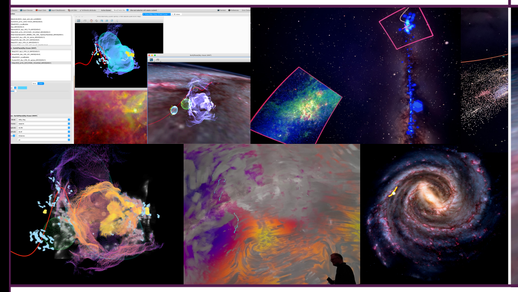
OpenSpace

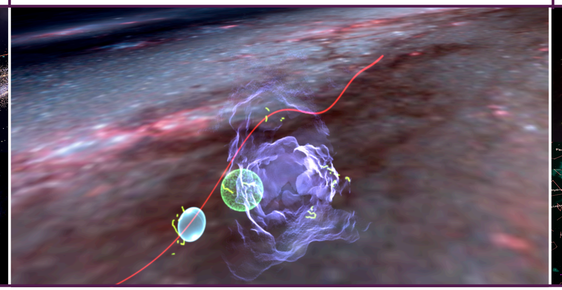
real-time data exploration
anywhere, including in planetaria

CosmicDS

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

Lead: Jackie Faherty, AMNH



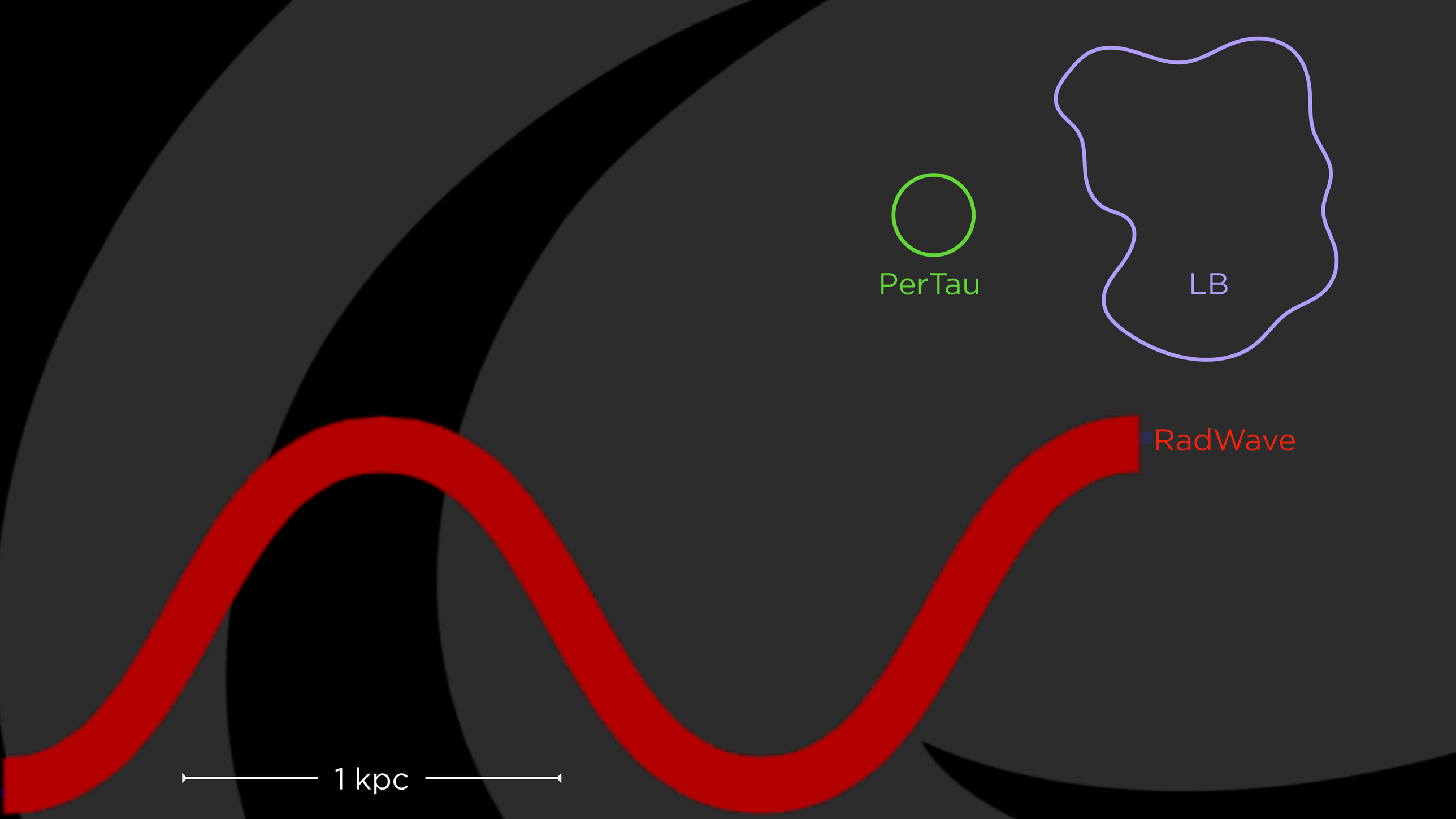


TEAM: Harvard/Smithsonian CfA (Jonathan Carifio, Alyssa Goodman, Ralf Konietzka, Theo O'Neill, Patricia Udomprasert, Catherine Zucker), **AMNH** (Brian Abbott, Micah Acinapura, Carter Emmart, Jackie Faherty); **Linkoping University** (Alex Bock) ; **University of Vienna** (Joao Alves, Sebastian Ratzenbock); **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?!

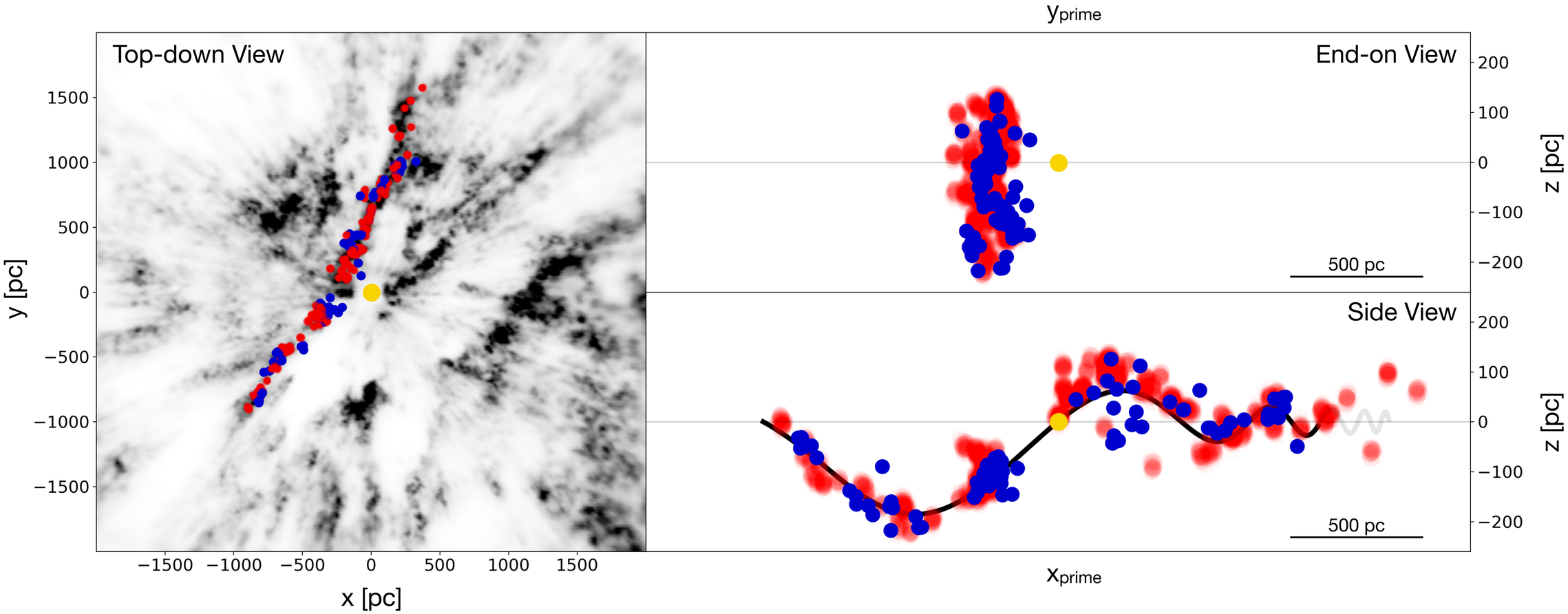
Join us, contribute, and yes, you get a T-Shirt.

2010 2014 2015 2018 2020 2024 2021 2022 2024 2022

Nessie Bones Skeleton Perseus RadWave PerTau LB Barnard++

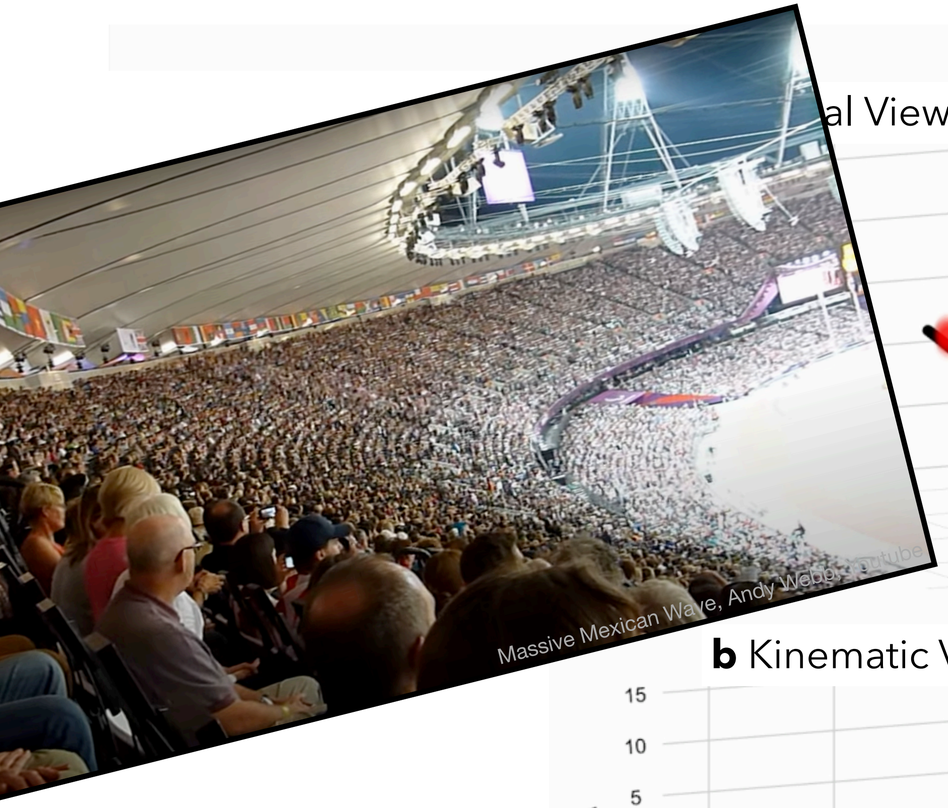

PerTau
LB
RadWave
1 kpc

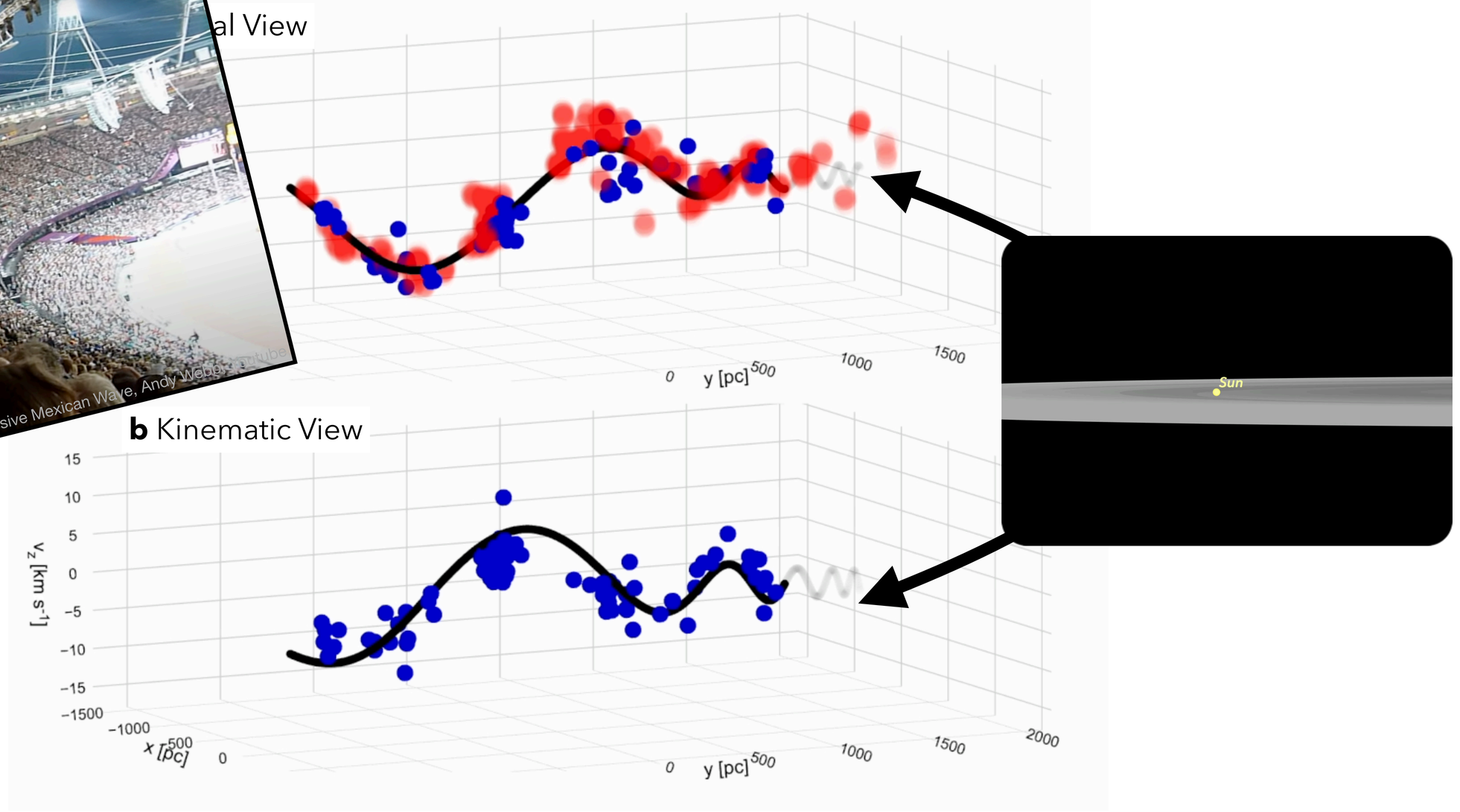
The Radcliffe Wave



The Wave is oscillating

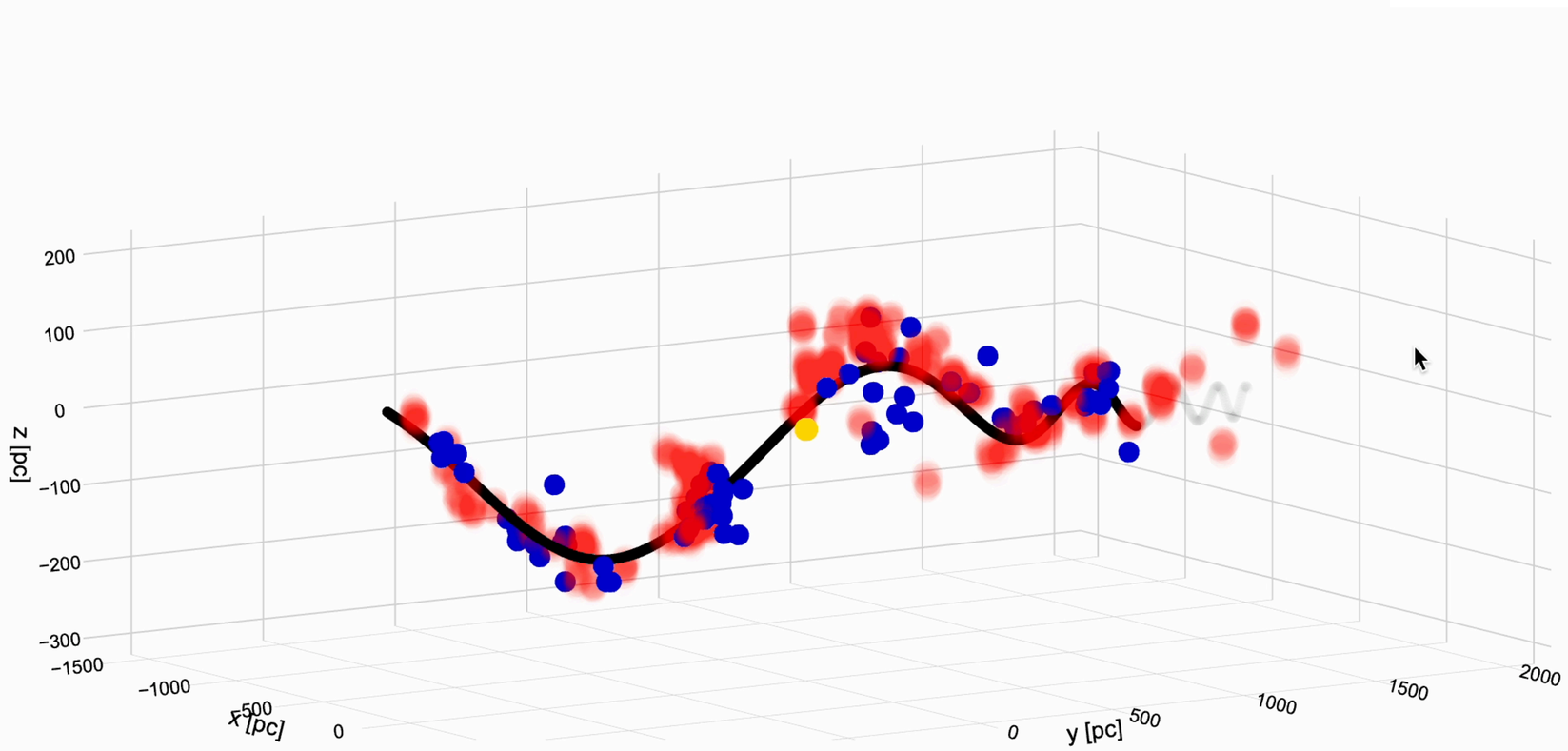
Konietzka, R., Goodman, A., Zucker, C., Burkert, A., Alves, J., Foley, M., Swiggum, C., Koller, M., Miret-Roig, N. 2024, *Nature*





The Wave is drifting away from us

Konietzka, R., Goodman, A., Zucker, C., Burkert, A., Alves, J., Foley, M., Swiggum, C., Koller, M., Miret-Roig, N. 2024, *Nature*



Show / Hide

- Sun
- Lines of Sight
- Best Fit
- Molecular Clouds
- Stellar Cluster
- Outlier
- Galactic Plane
- Radial Drift
- Tangential Drift

Play | Pause | Reverse

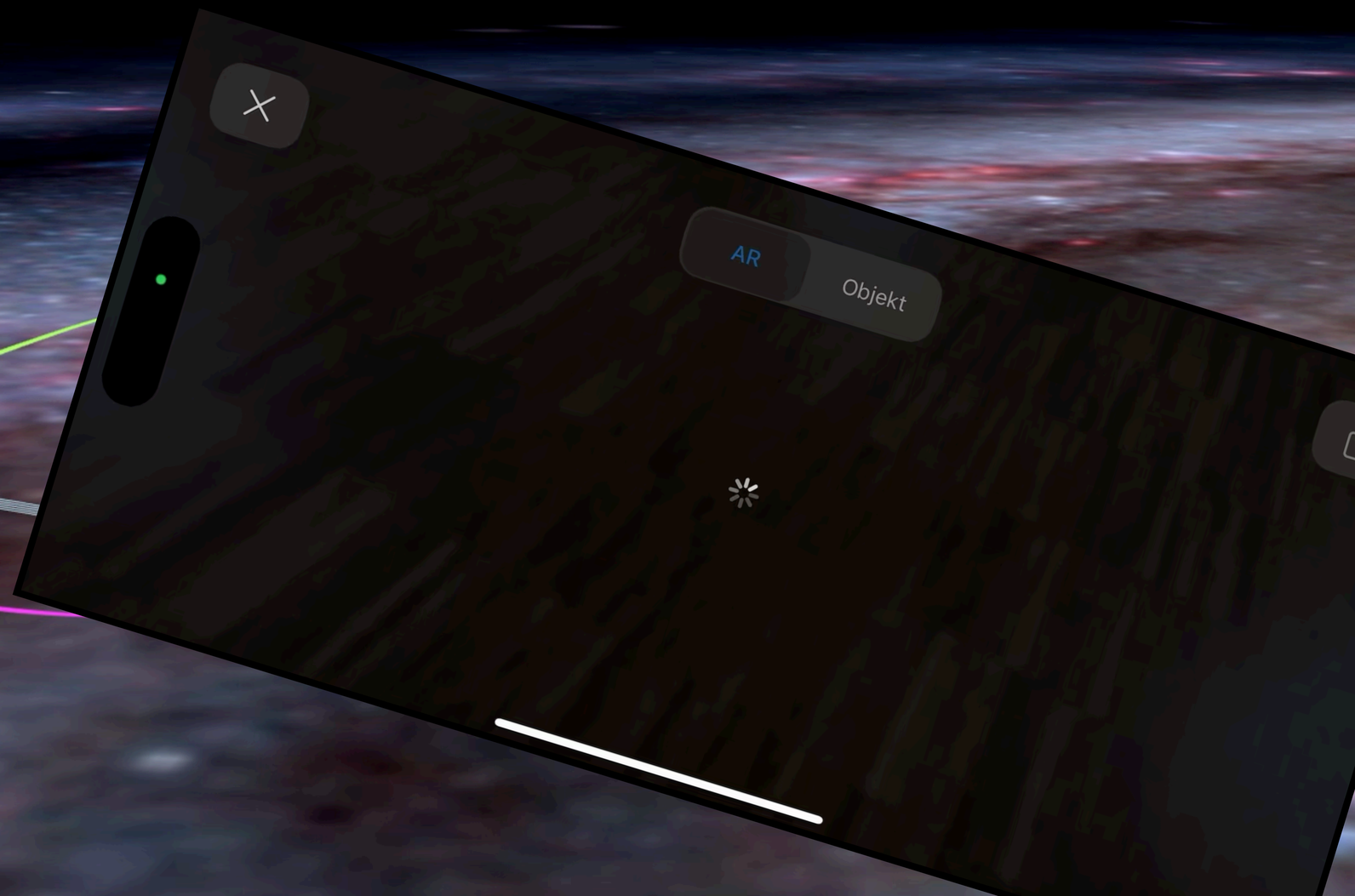
Time: 0 Myr

0 Myr 6 Myr 13 Myr 20 Myr 27 Myr 33 Myr 40 Myr 47 Myr 54 Myr 61 Myr 67 Myr 74 Myr 81 Myr 88 Myr 95 Myr

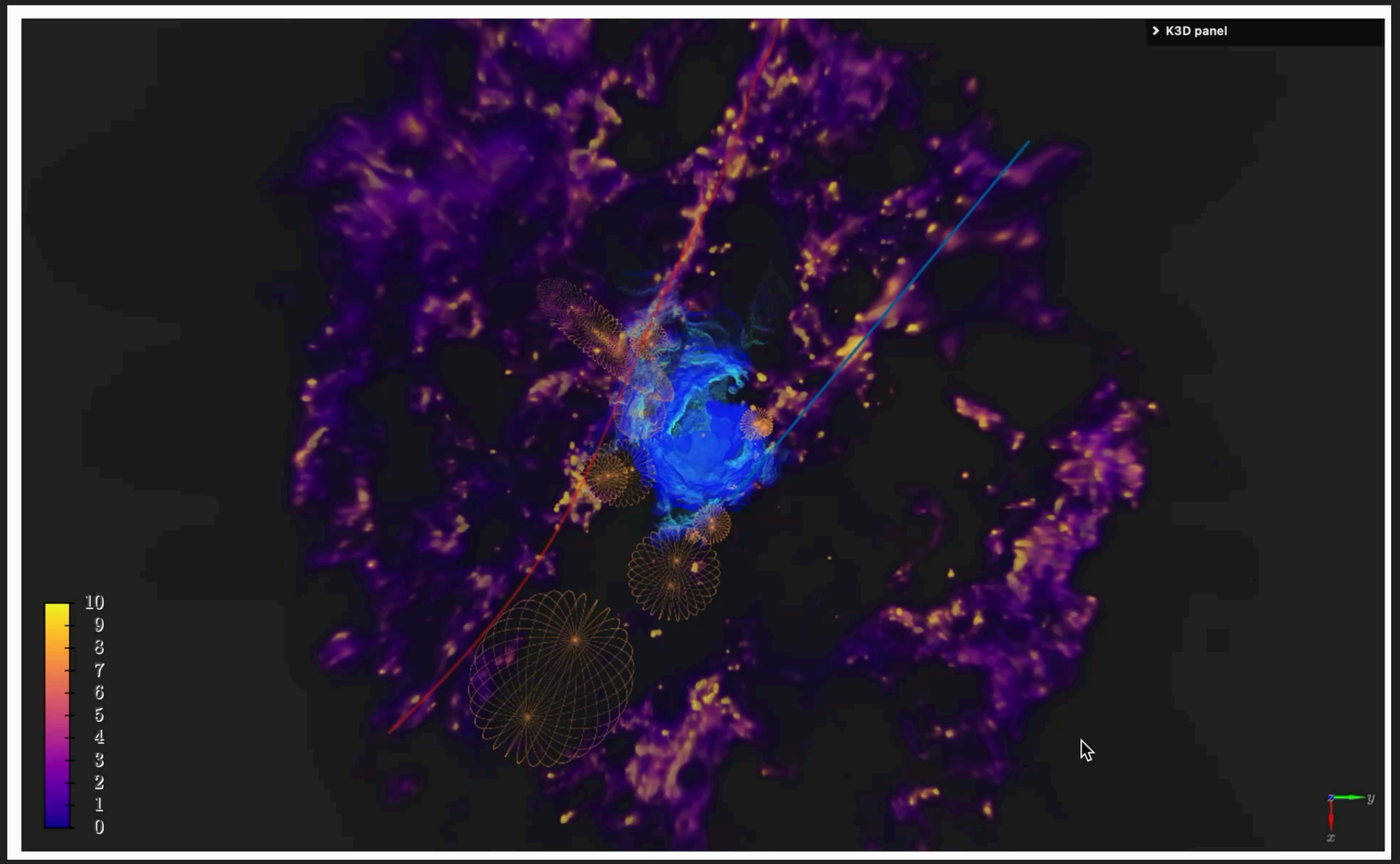
The Radcliffe Wave is oscillating

Konietzka, R., Goodman, A., Zucker, C., Burkert, A., Alves, J., Foley, M., Swiggum, C., Koller, M., Miret-Roig, N. 2024, *Nature*

Scan me



“Everything, Everywhere, All at Once”



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

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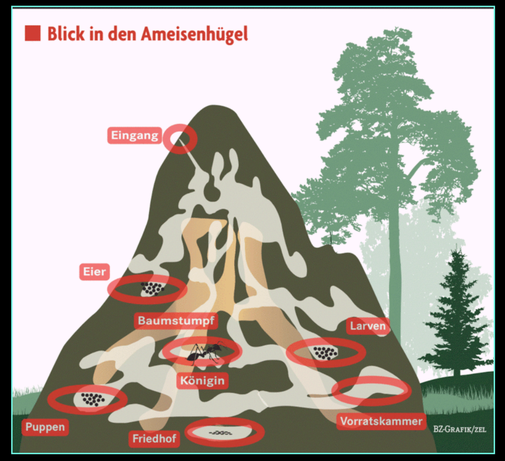
Self-organisation at the edge of chaos

Self-organisation: Individual objects organise their joint behaviour by local interactions amongst themselves. No invisible hand is needed.

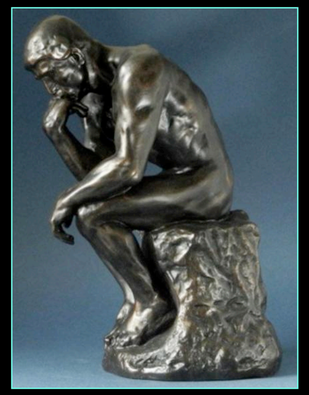
⟶ spontaneous global order

Emergent overarching structures and complex behaviours (swarm intelligence) appear that cannot be understood in isolation



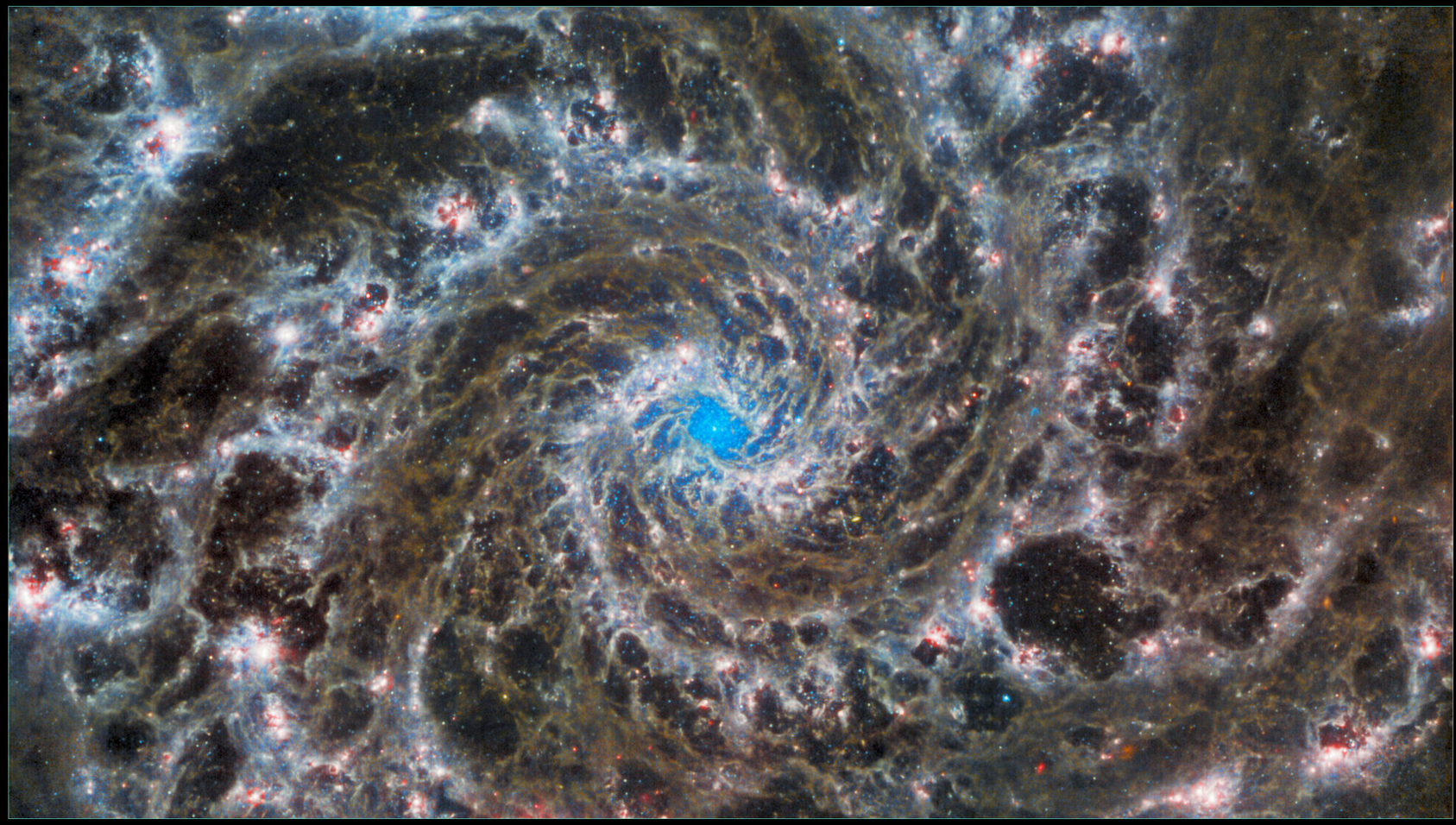
Ant Hill

self consciousness



SIMCITY

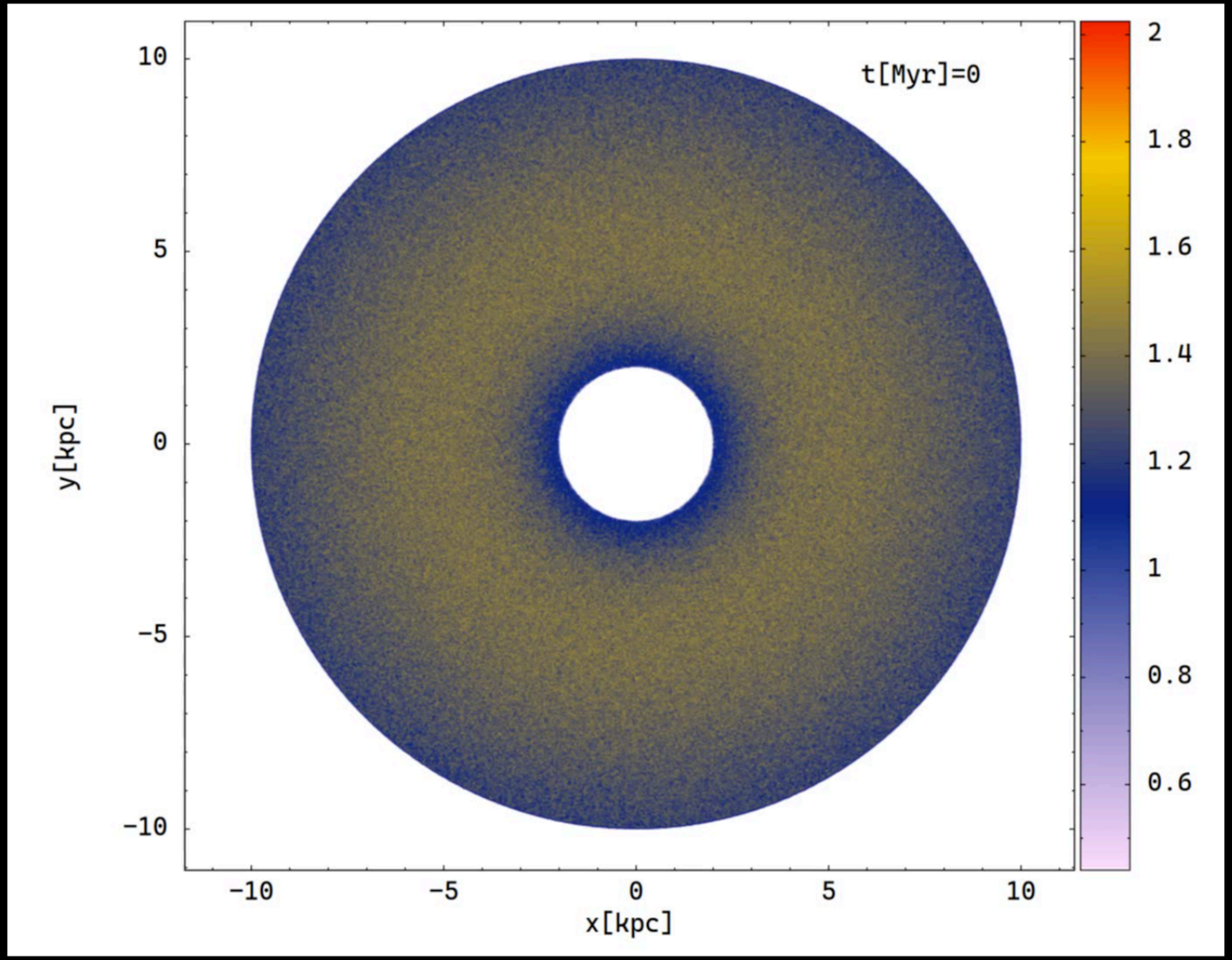
Is this Self-organised Complexity at the Edge of Chaos



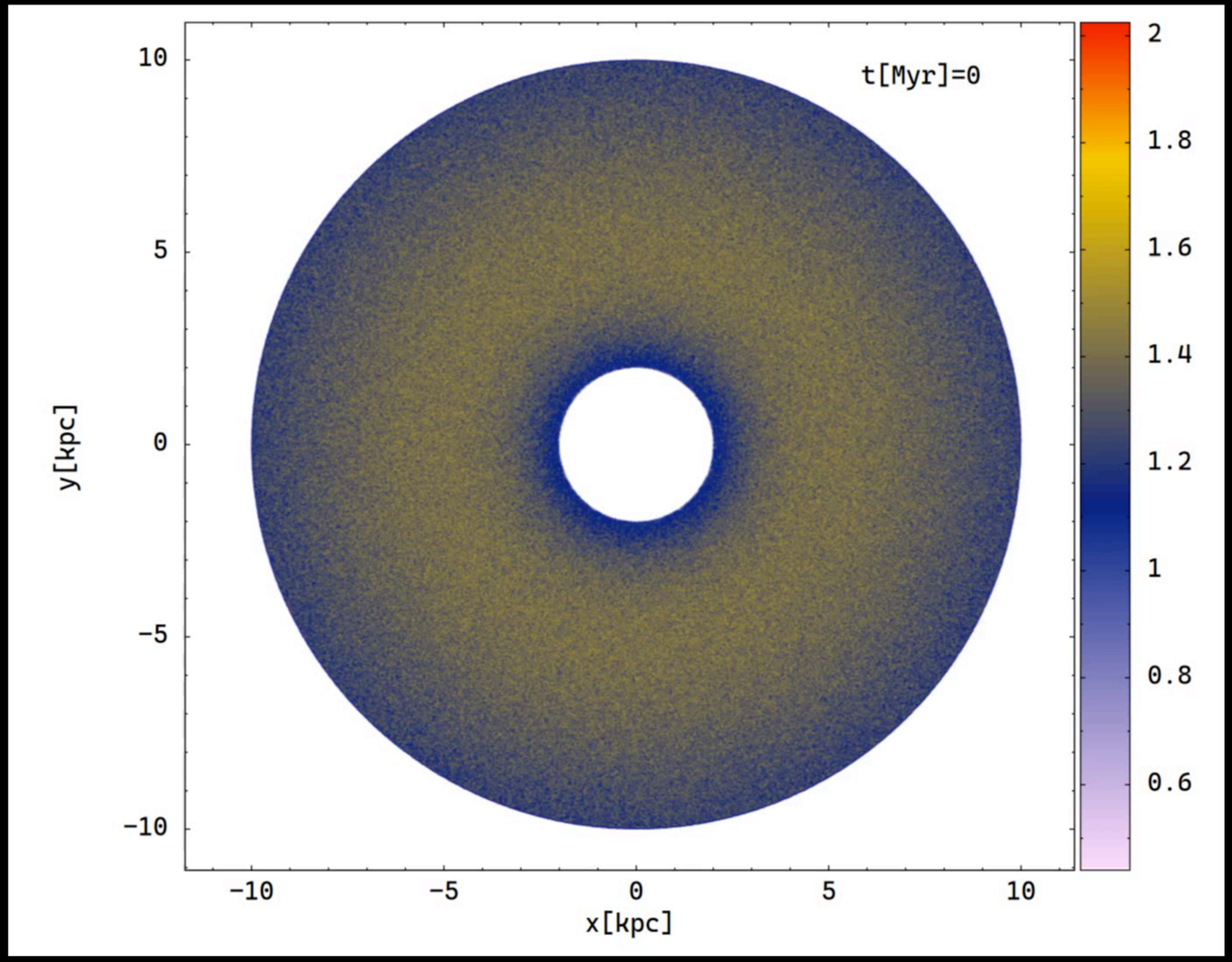
Lee & PHANGS JWST

The Phantom Galaxy, M74

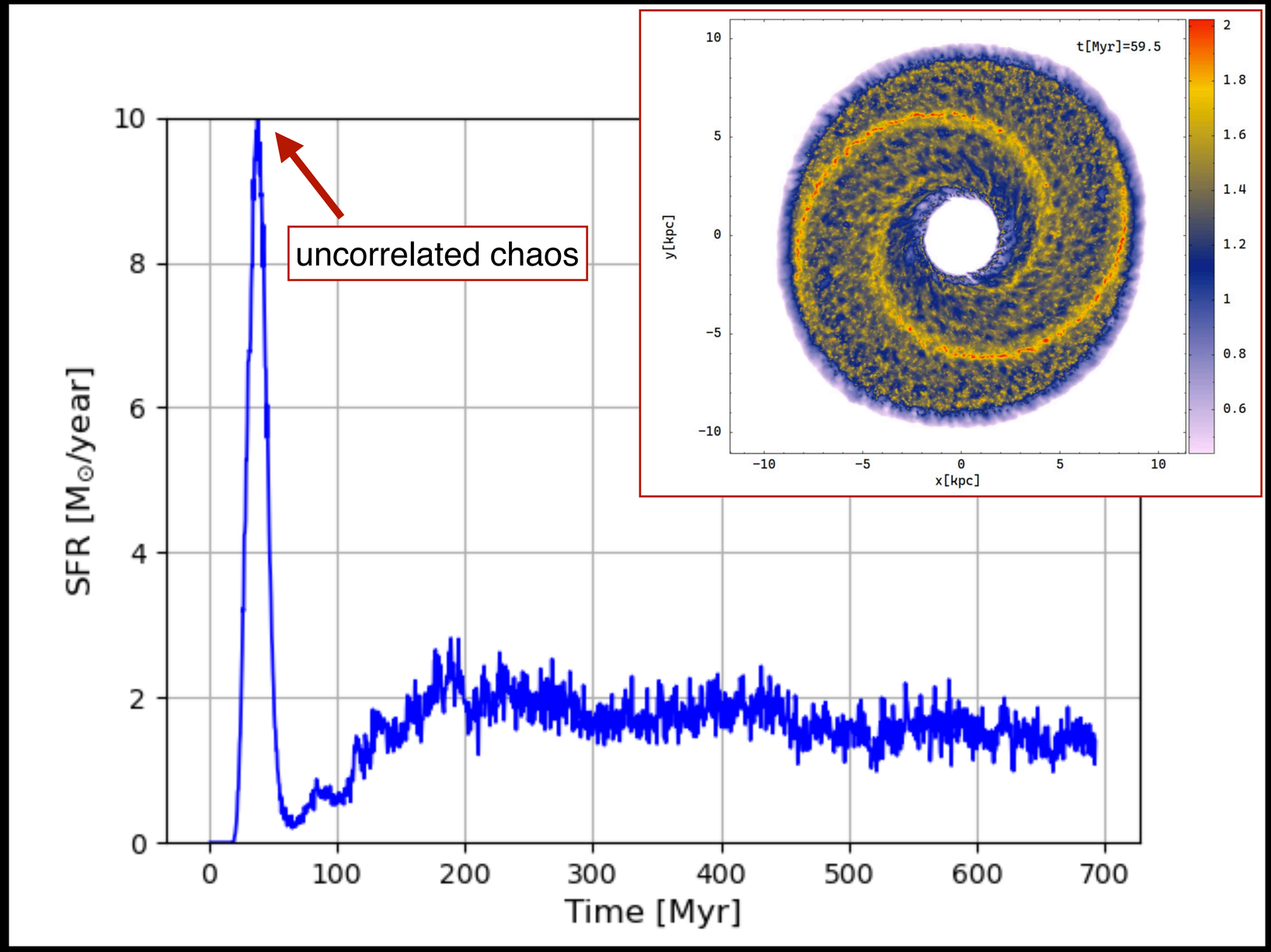
Initial condition: homogeneous gas disk



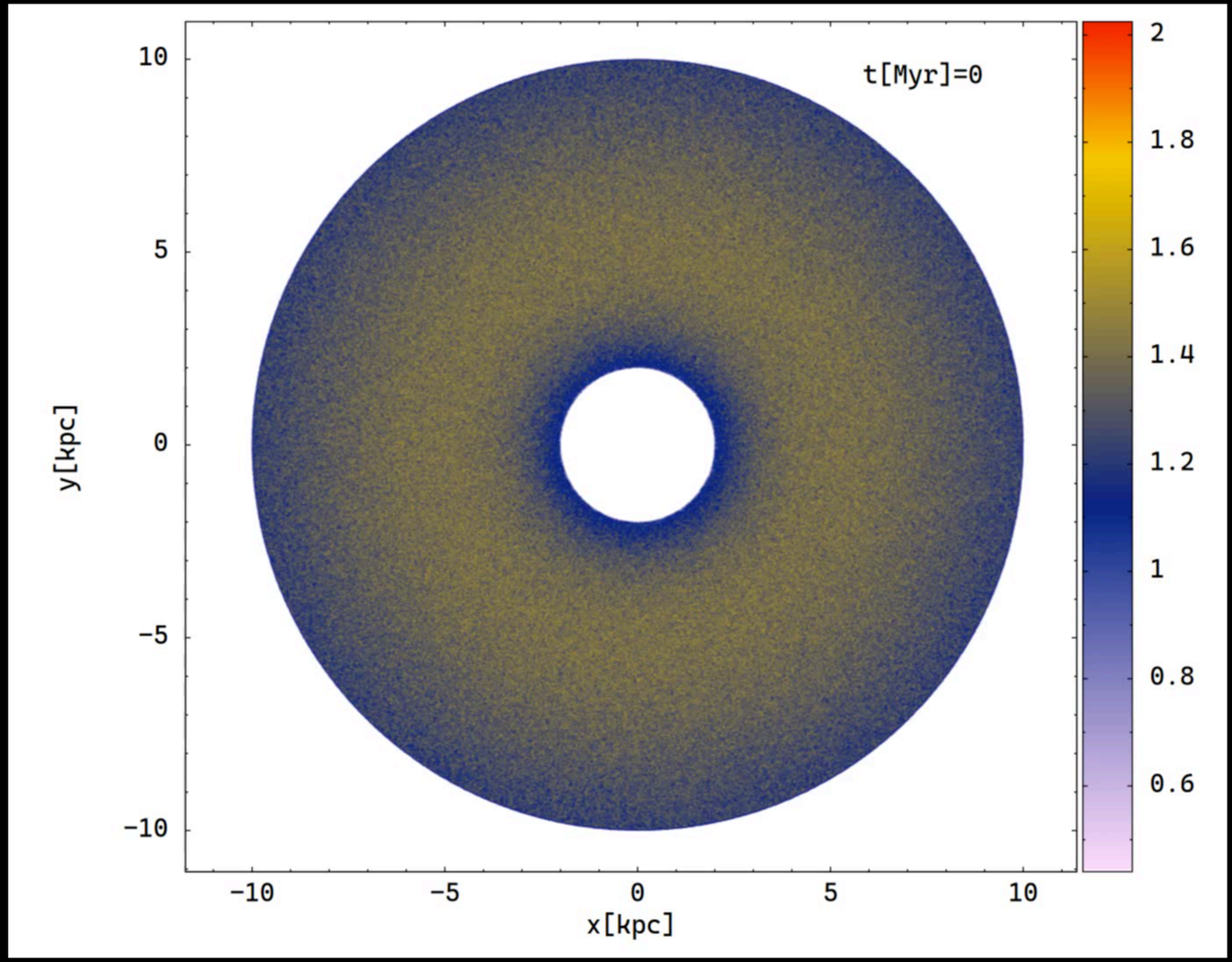
Alig & Burkert


t[Myr]=0
10
5
0
−5
−10
y[kpc]
−10
−5
0
5
10
x[kpc]
2
1.8
1.6
1.4
1.2
1
0.8
0.6

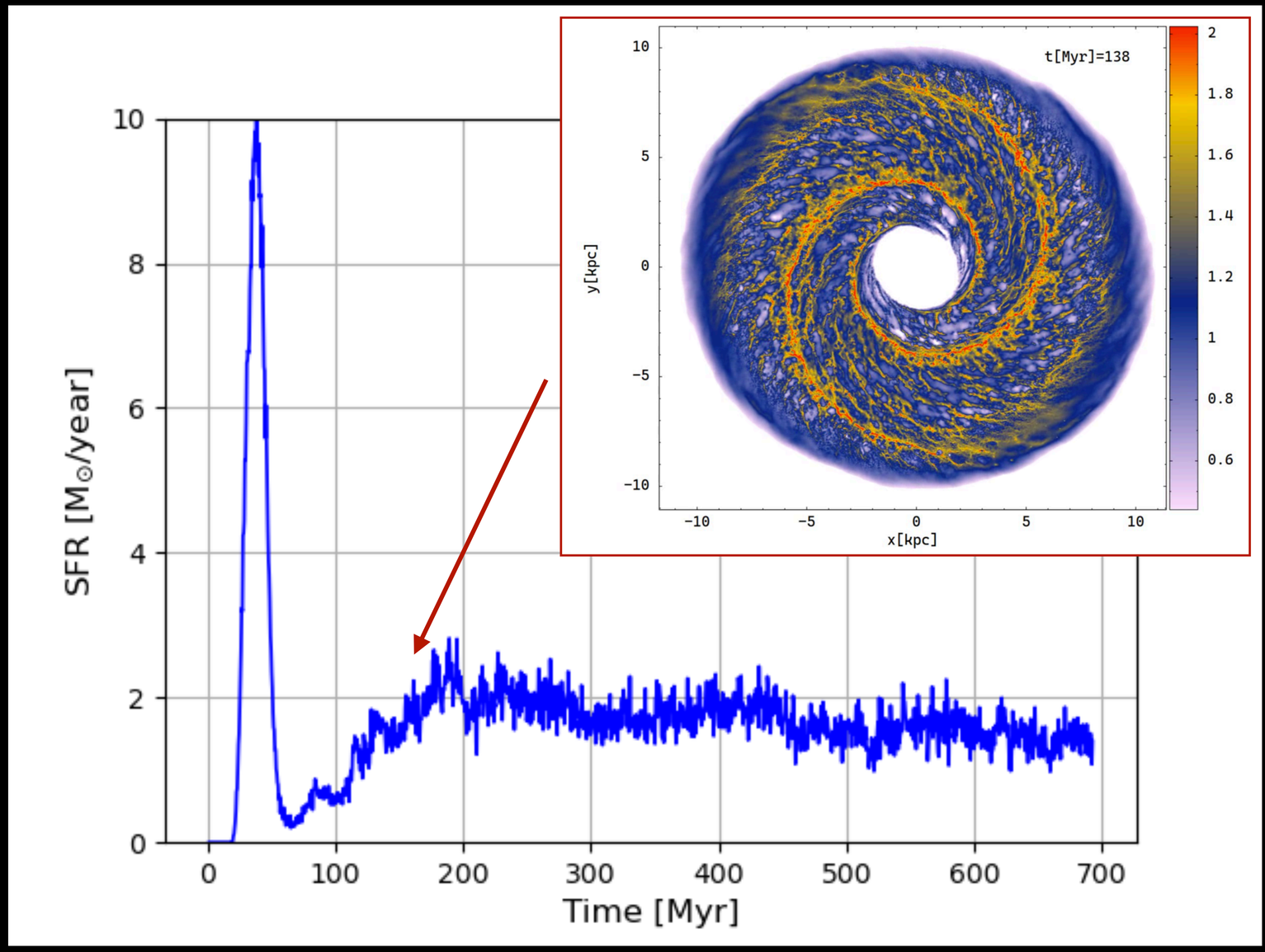
Uncorrelated Chaos (galaxies at cosmic dawn?)



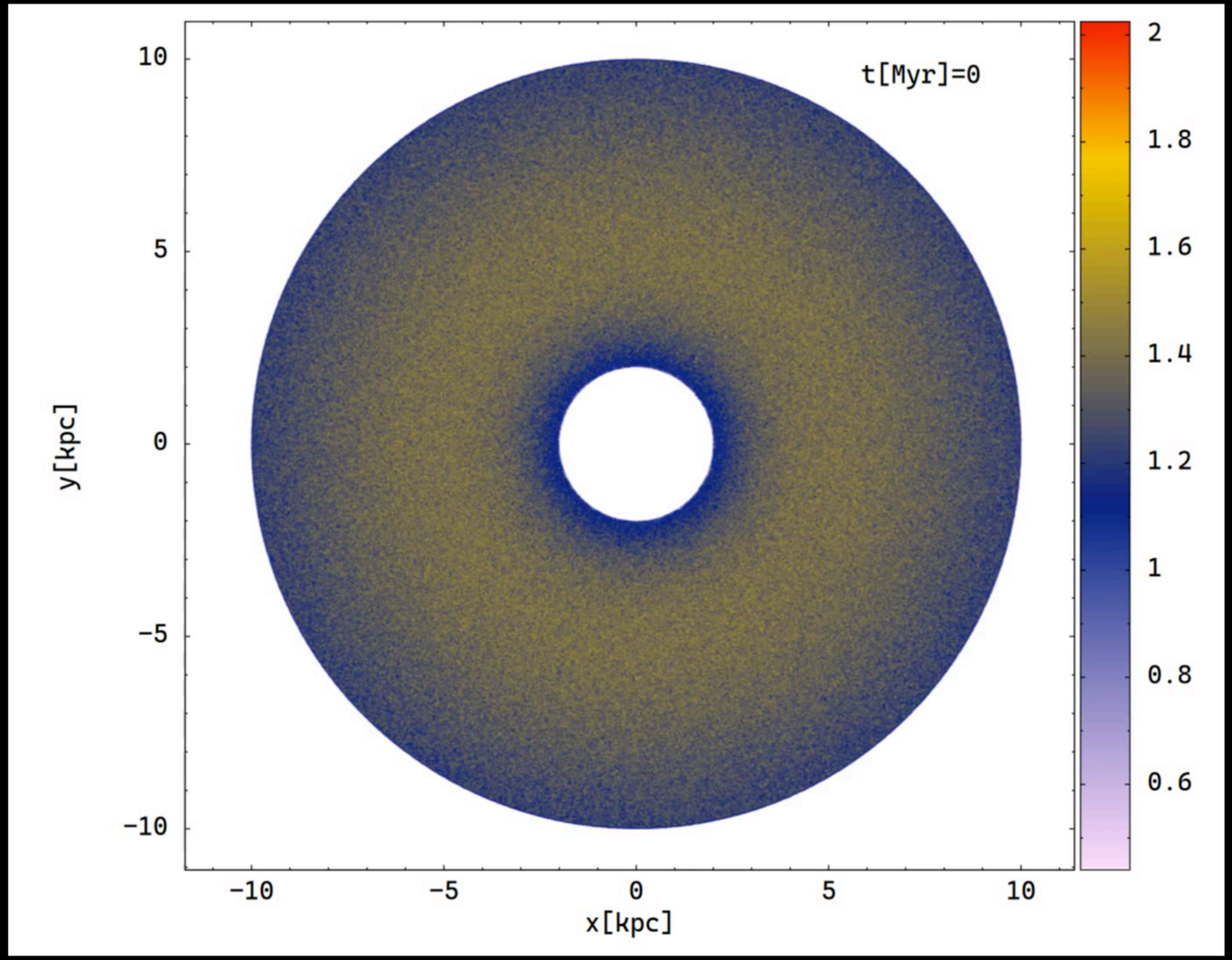
Self-organised complexity emerges from the inside out

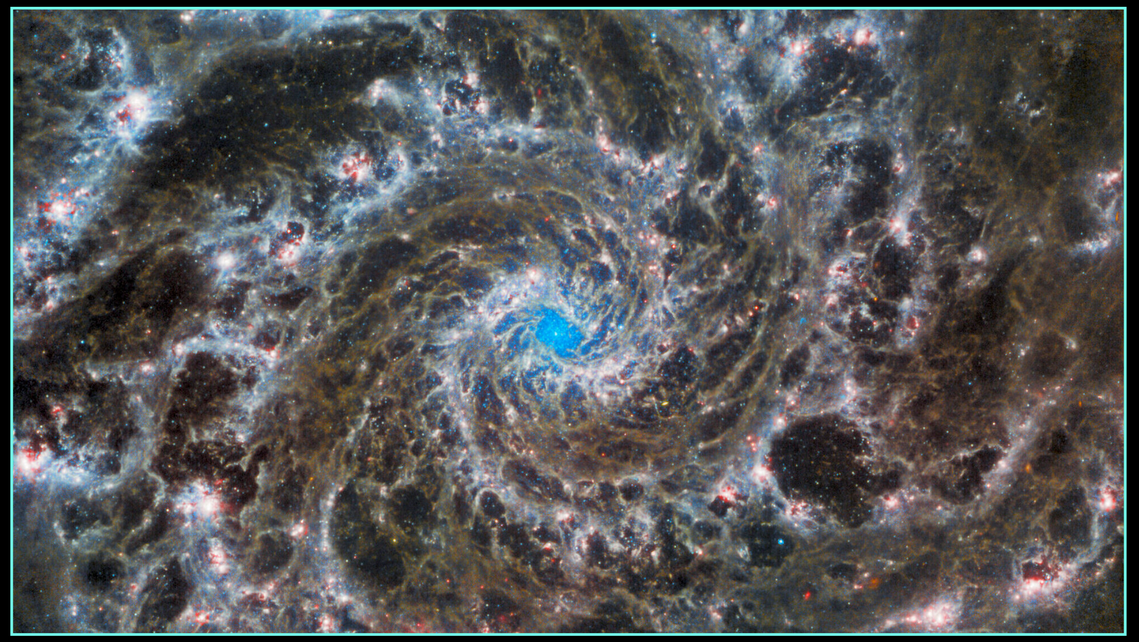


Emergent property: Constant global star formation rate



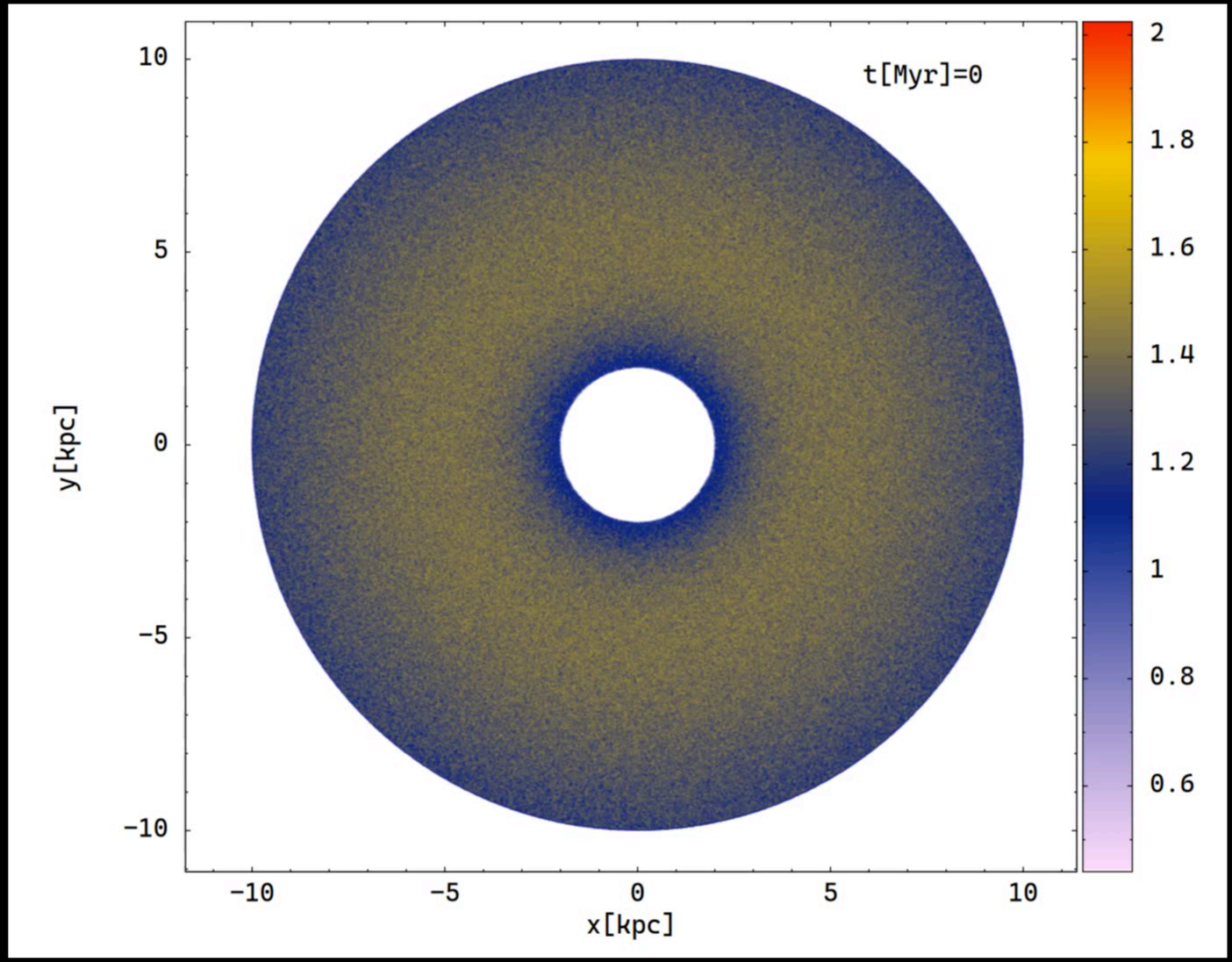
Self-organised statistic equilibrium



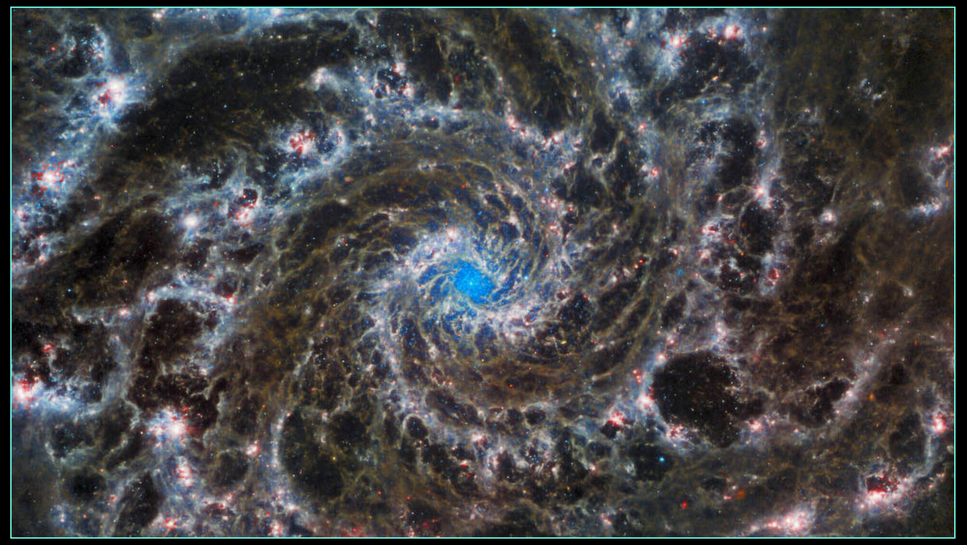


WHAT IS THIS??

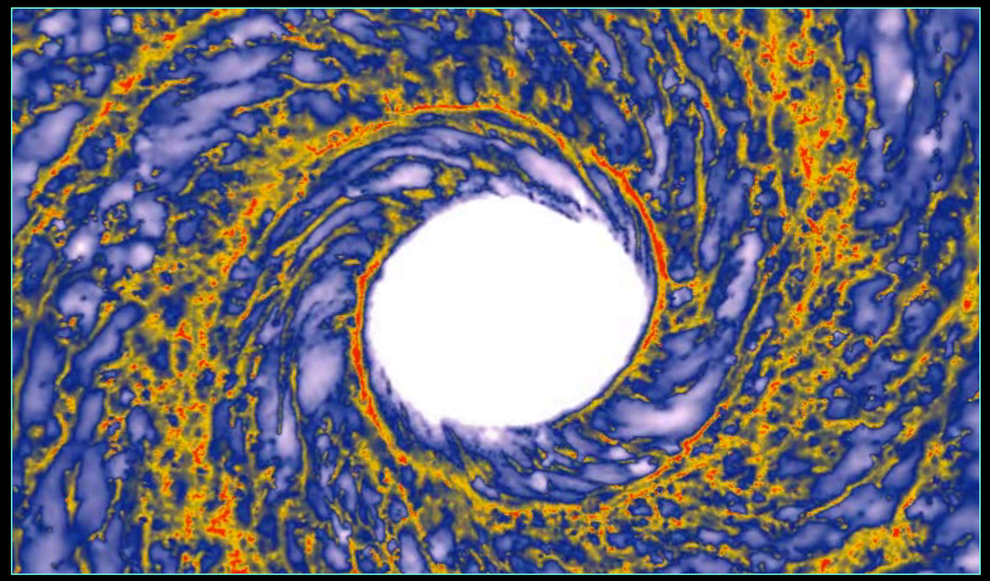
A super-bubble forms and travels through the disk



Are galaxies in a state of self-organised complexity far from equilibrium?



Are our methods sophisticated enough
to capture this complexity?



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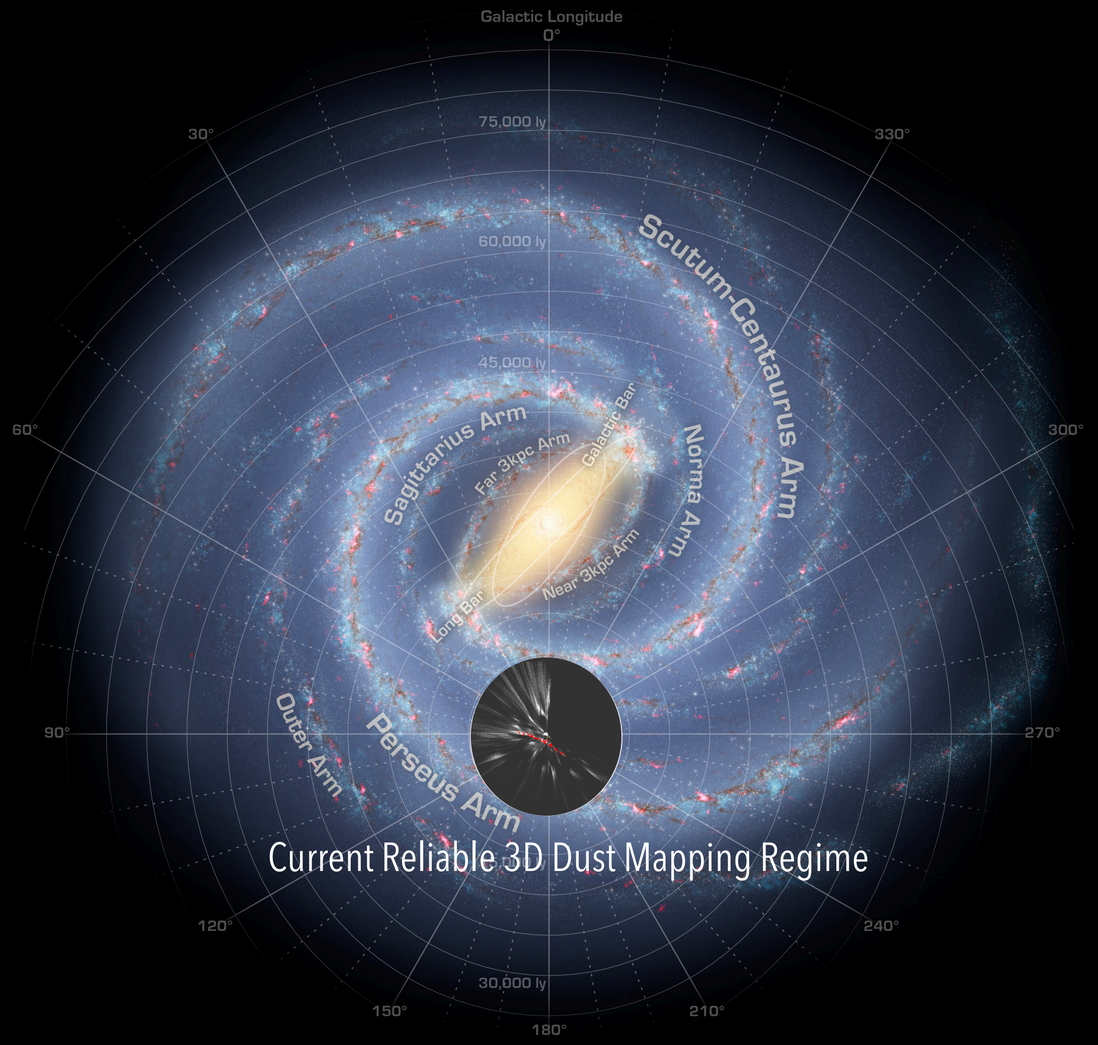
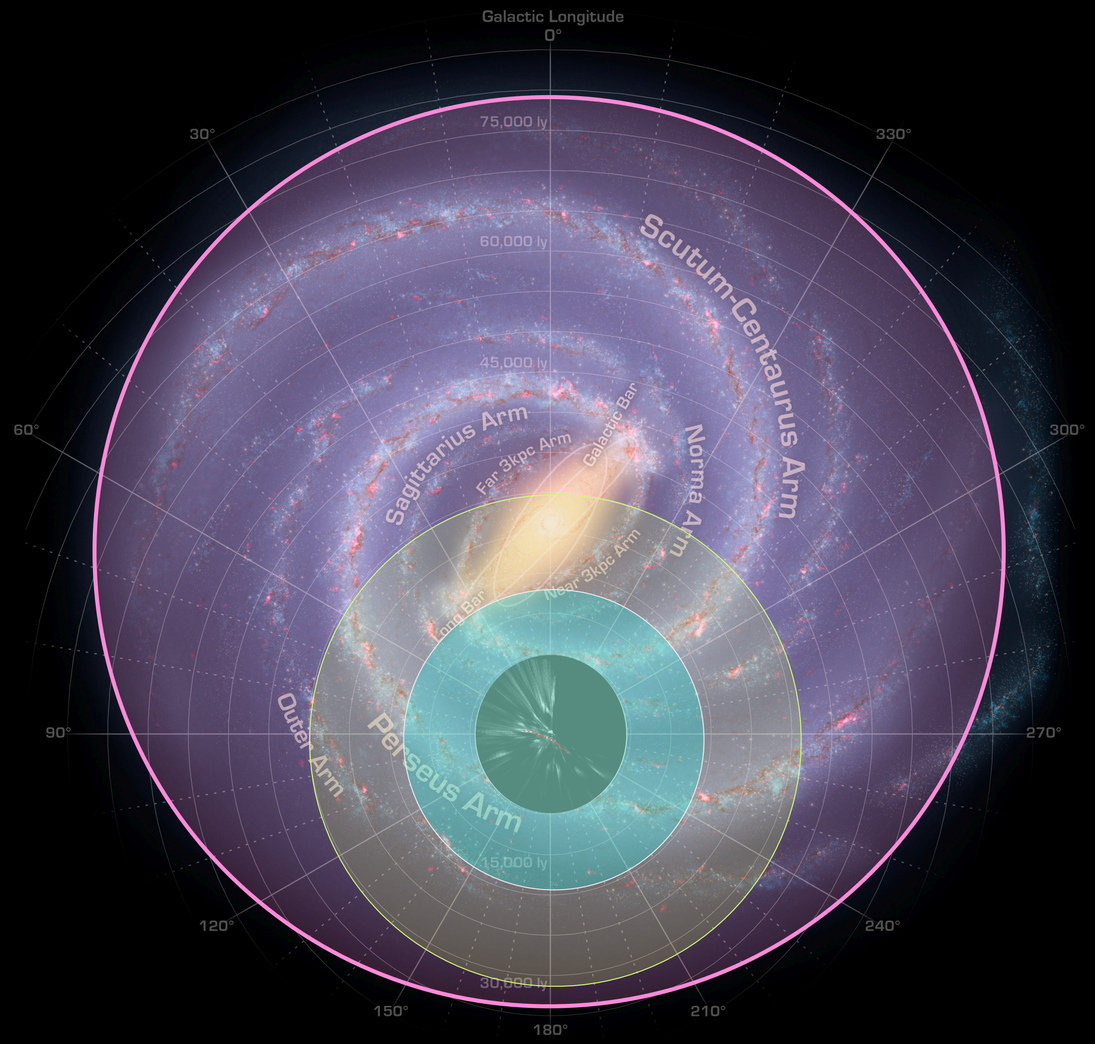

Galactic Longitude
0°
30°
330°
60°
300°
90°
270°
120°
240°
150°
210°
180°
75,000 ly
60,000 ly
45,000 ly
30,000 ly
Scutum-Centaurus Arm
Sagittarius Arm
Norma Arm
Perseus Arm
Outer Arm
Galactic Bar
Far 3kpc Arm
Near 3kpc Arm
Long Bar
Current Reliable 3D Dust Mapping Regime



Roman (+LSST)

IR Photometry for tens of billion stars
& proper motions for billions of stars?

VVV, UKIDSS,DECaPS

IR Photometry for 3 billion stars

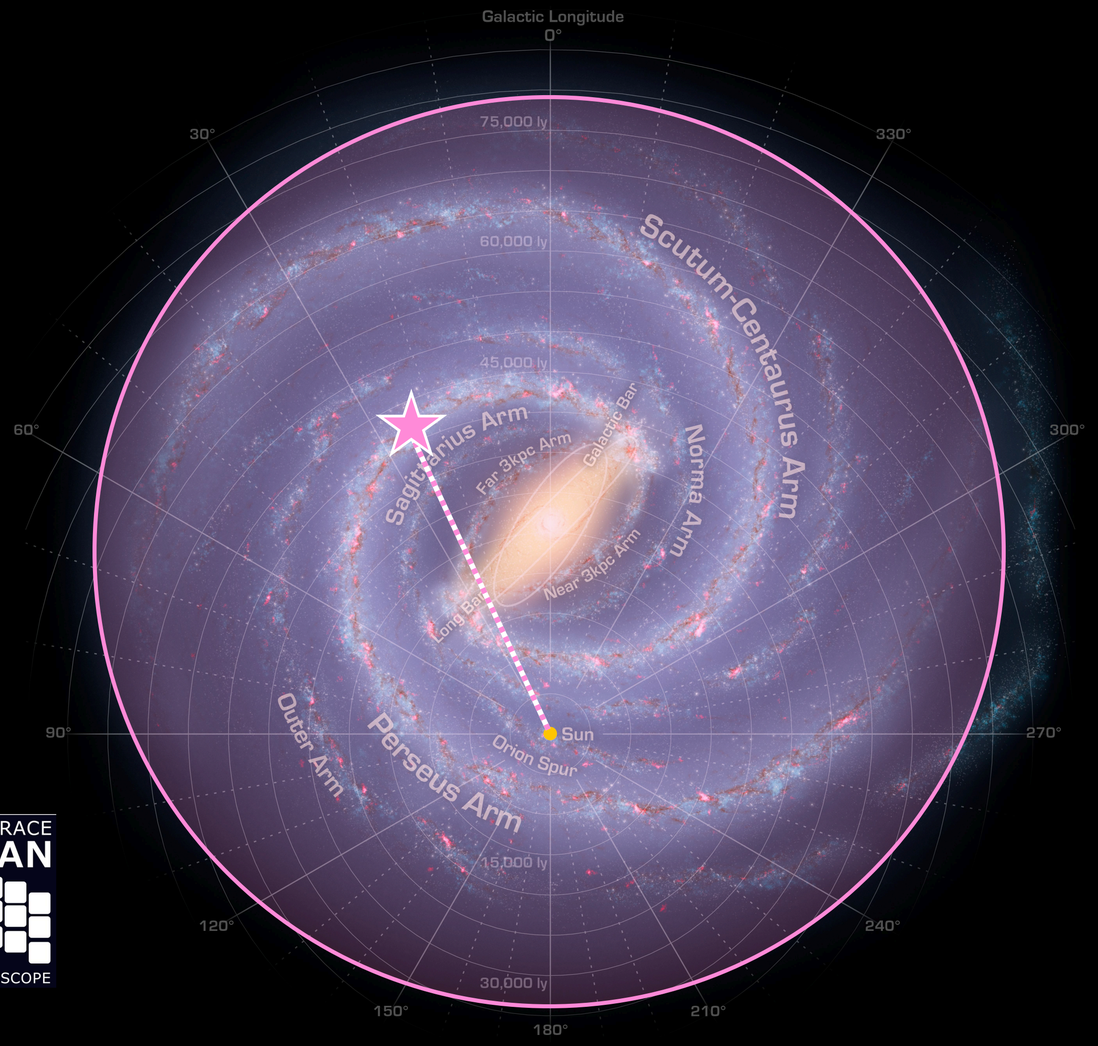
SDSS-V

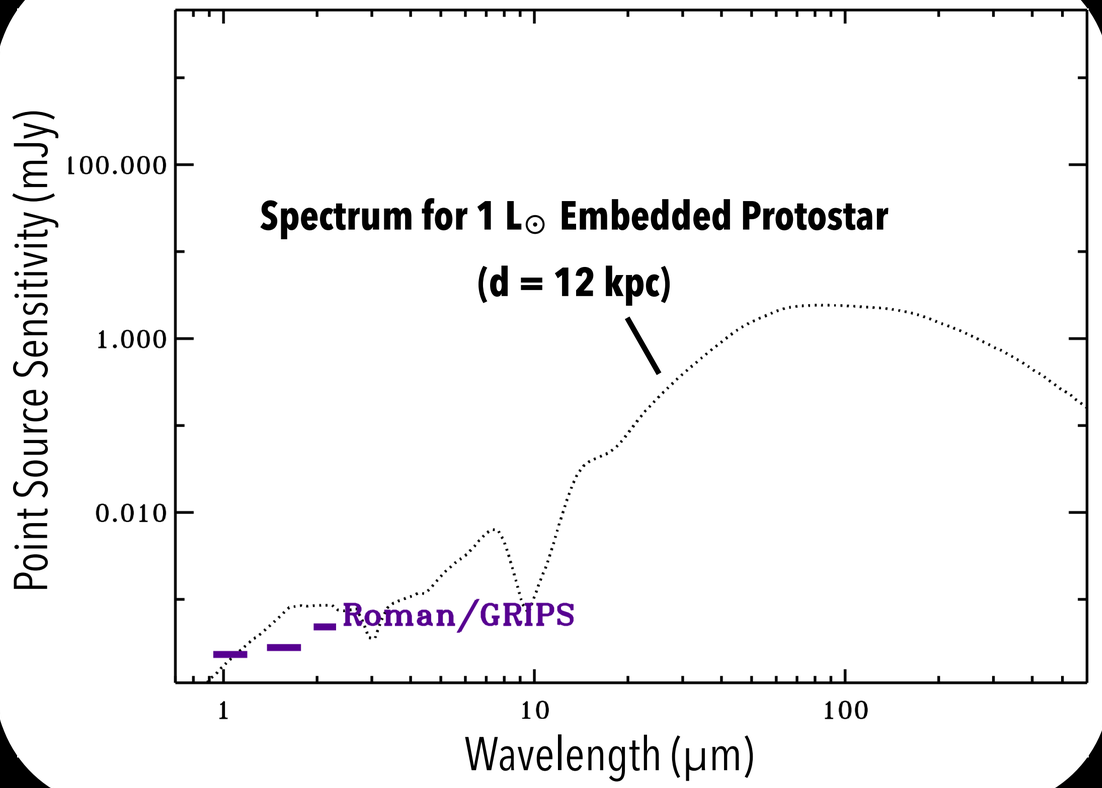
IR Spectroscopy for ~4 million stars

NANCY GRACE ROMAN SPACE TELESCOPE

DECaPS

SDSS-V





NANCY GRACE ROMAN SPACE TELESCOPE

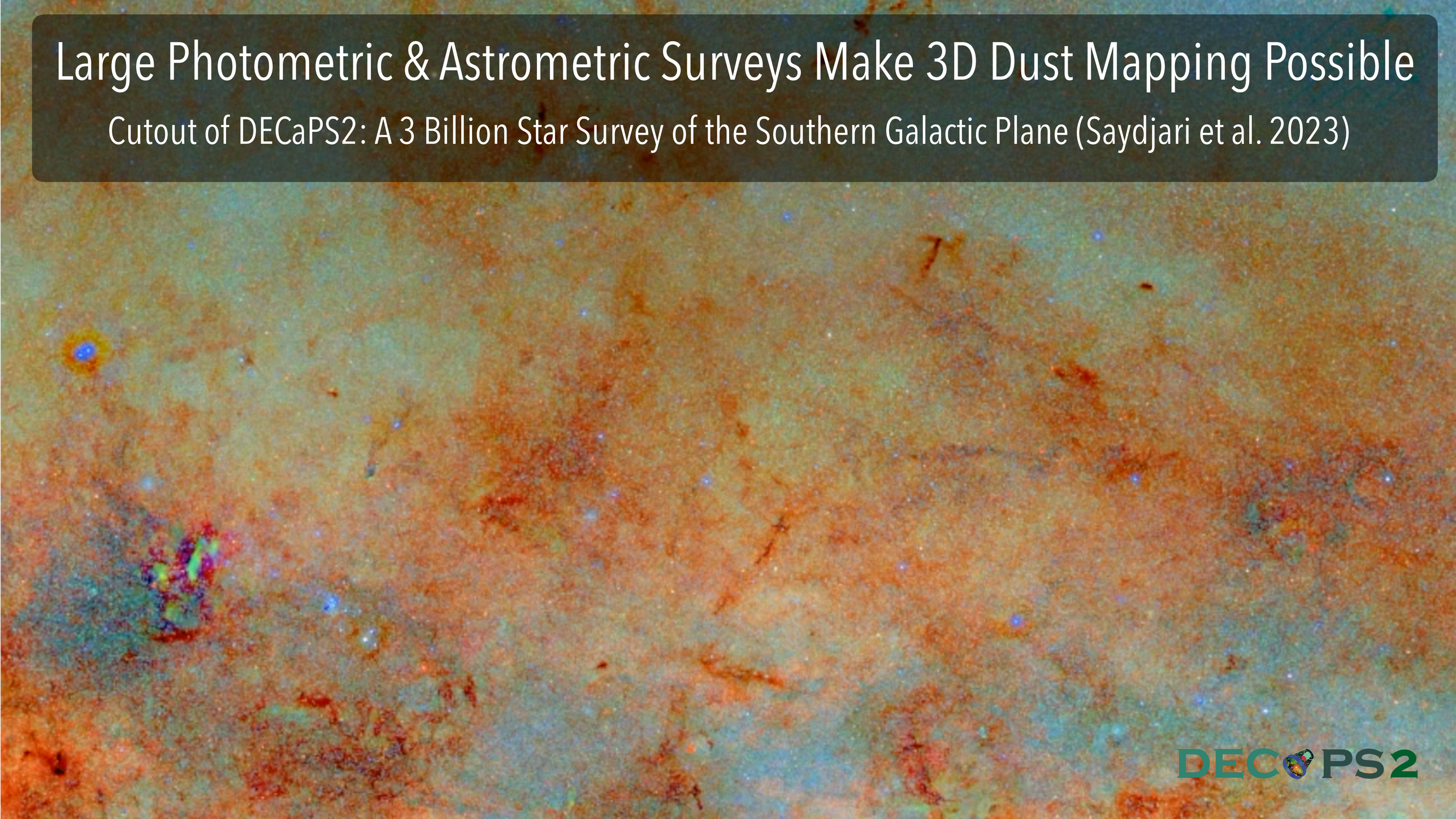
"GRIPS" = Galactic Roman Infrared Plane Survey. Approved by NASA for Early Definition
(see *Paladini, Zucker, & Benjamin et al. 2021 White Paper*)

Roman

IR Photometry for tens of billion stars
& proper motions for billions of stars

Large Photometric & Astrometric Surveys Make 3D Dust Mapping Possible

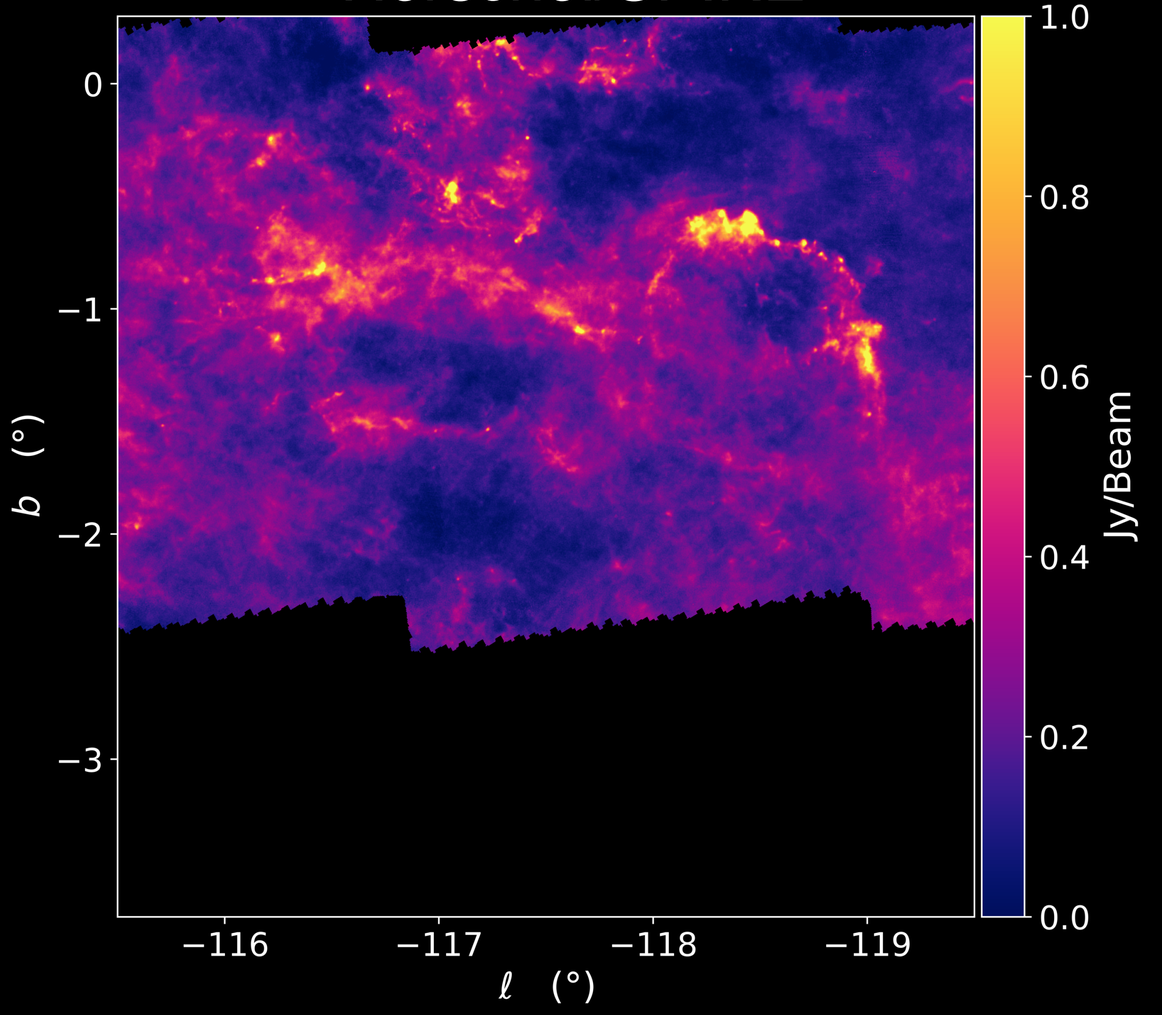
Cutout of DECaPS2: A 3 Billion Star Survey of the Southern Galactic Plane (Saydjari et al. 2023)



Comparing Dust Maps

Emission

Herschel/SPIRE

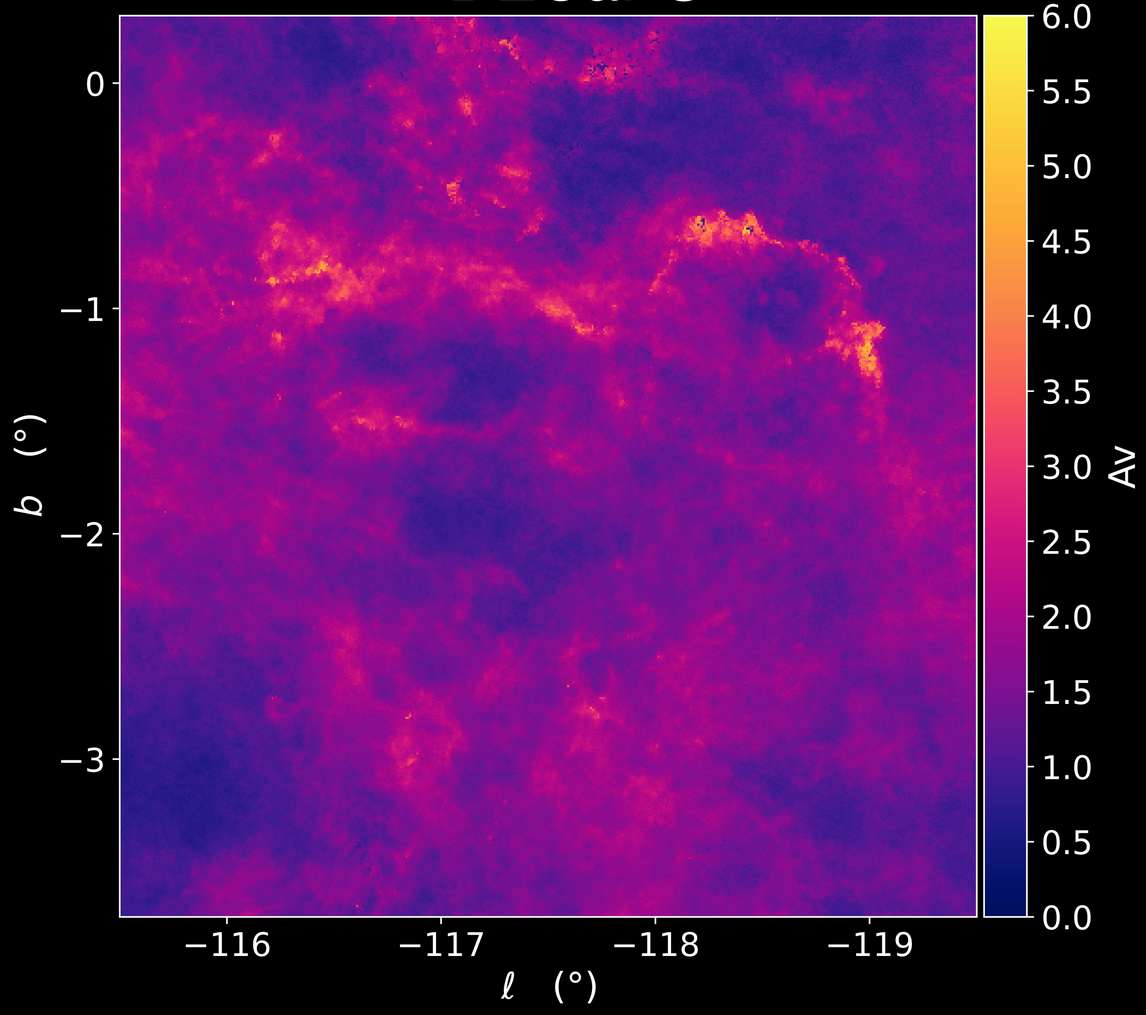


Wavelength: 500 μm
Citation: Griffin et al. (2010)

Coverage: ~2%
PSF FWHM: 36.6”
Max Distance: --

DECaPS

Extinction



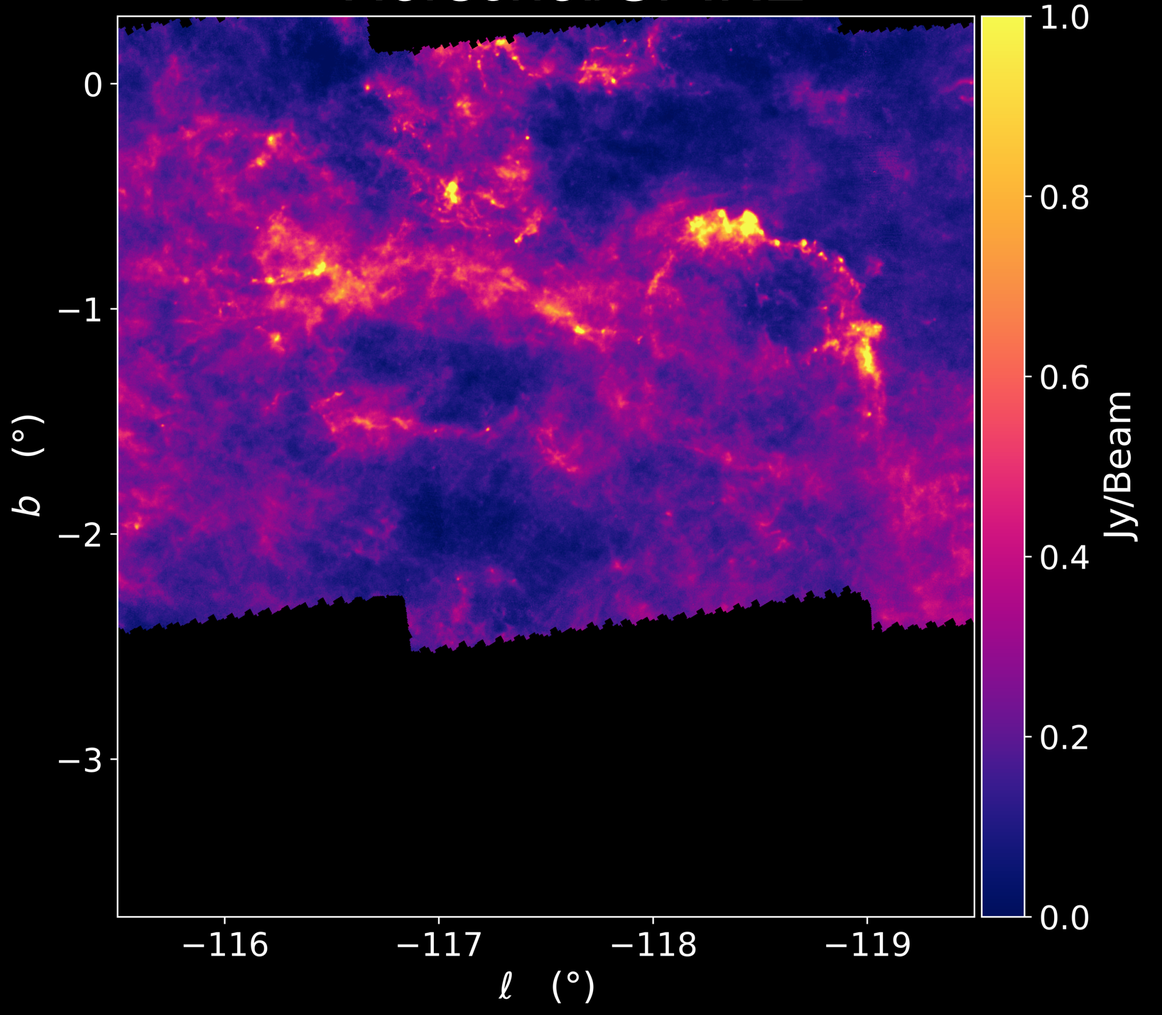
Wavelength: Optical-NIR-IR
Citation: Zucker/Saydjari/Speagle et al. (2024, in prep)

Coverage: 6.5%
PSF FWHM: 1’.07
Distance: ~7 kpc

But wait, DECaPS is 3D!

Emission

Herschel/SPIRE



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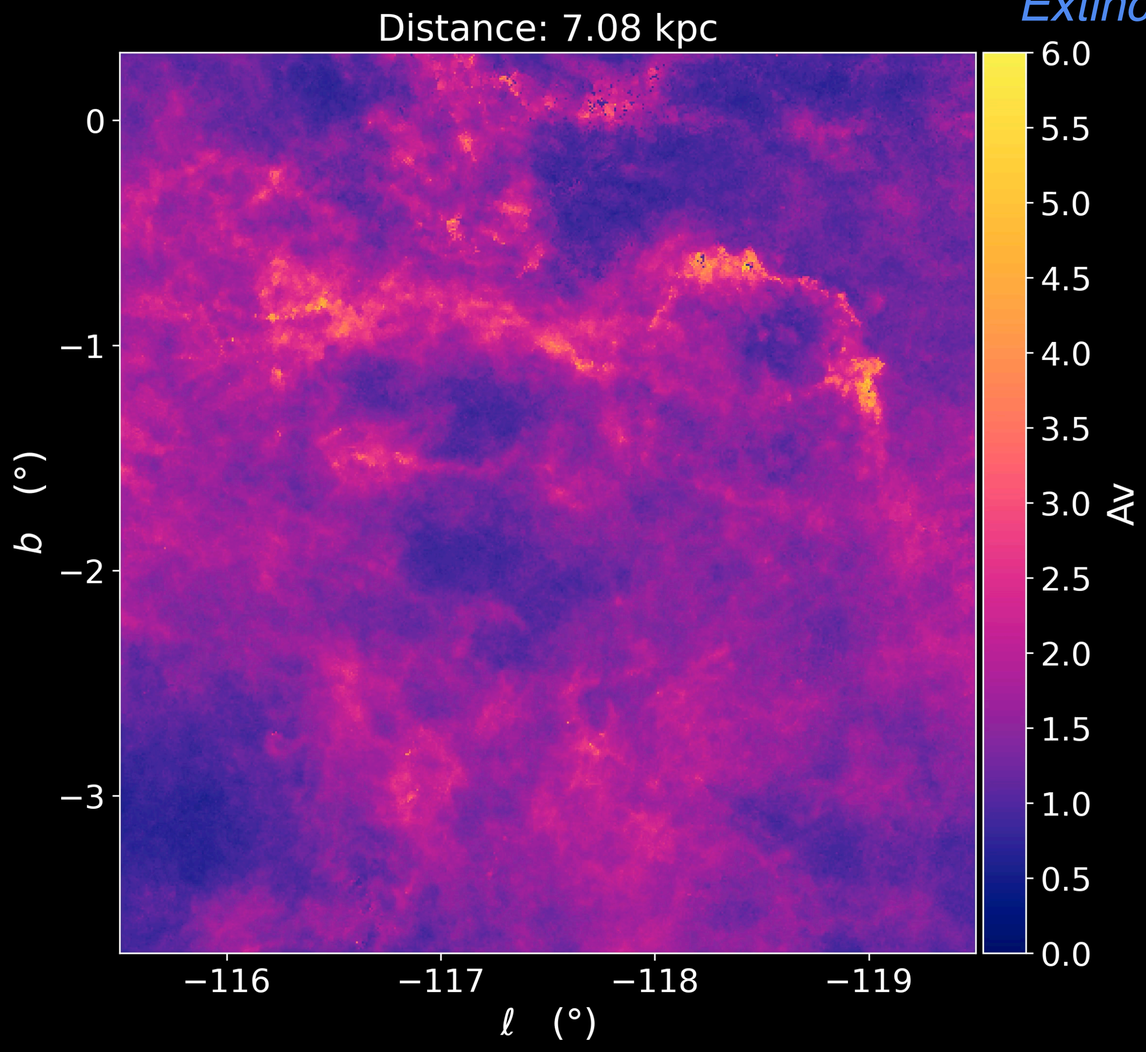

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