

# Balancing Artistic Expression and Scientific Rigor in Successful Visualizations for Communications

Robert Hurt

Caltech-IPAC, Pasadena, CA, USA

*Cosmic Explorations, Sept. 23 2022*

# Career Trajectory



→ Grad Student → Postdoc(x2) → Staff Scientist

→ Airbrush/Photo → Photoshop → 3D Graphics

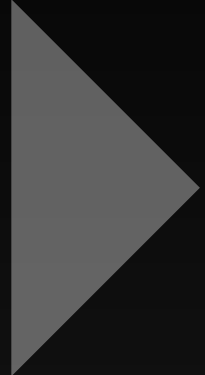


*Inspirations*



# Career Trajectory

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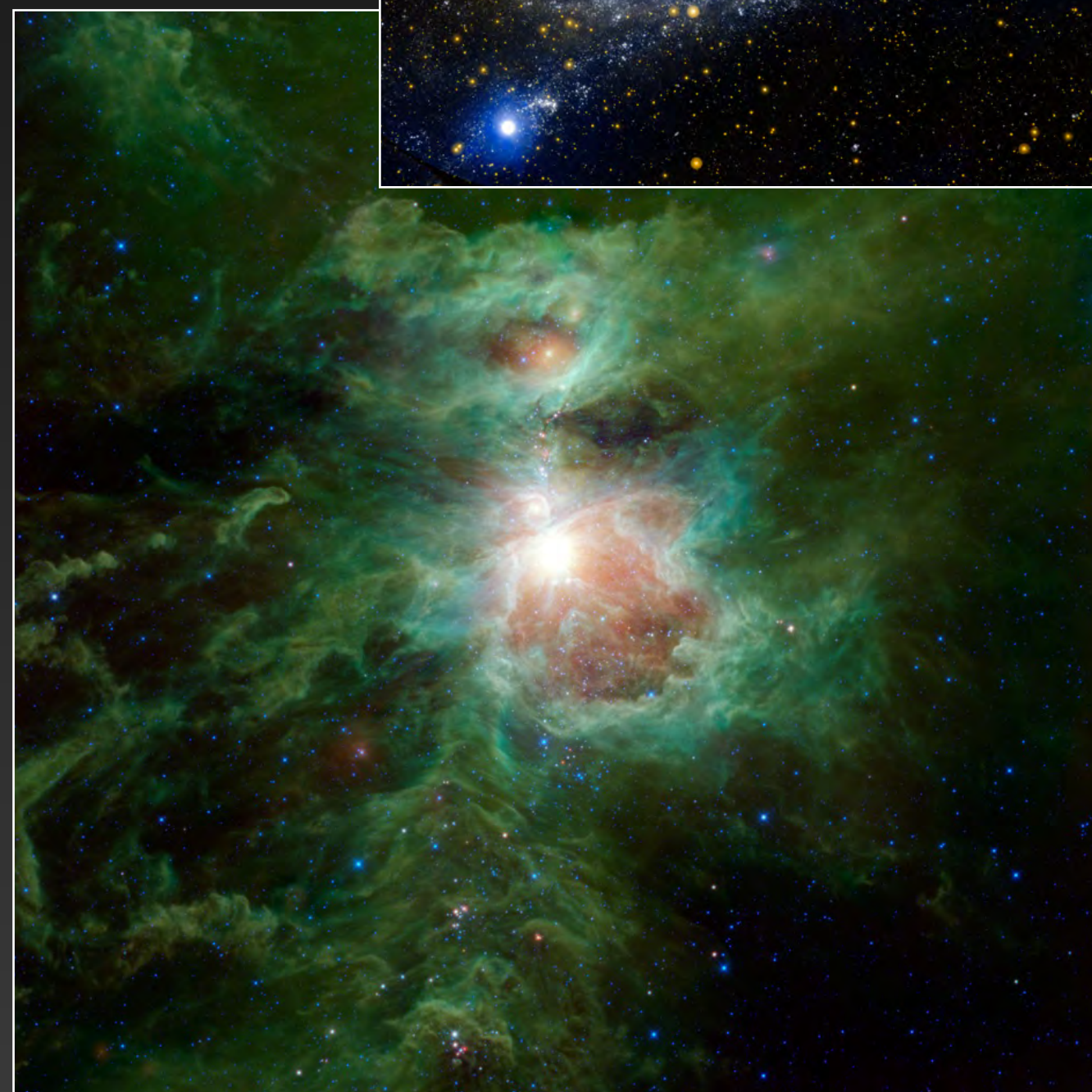


“Astrovizicist”

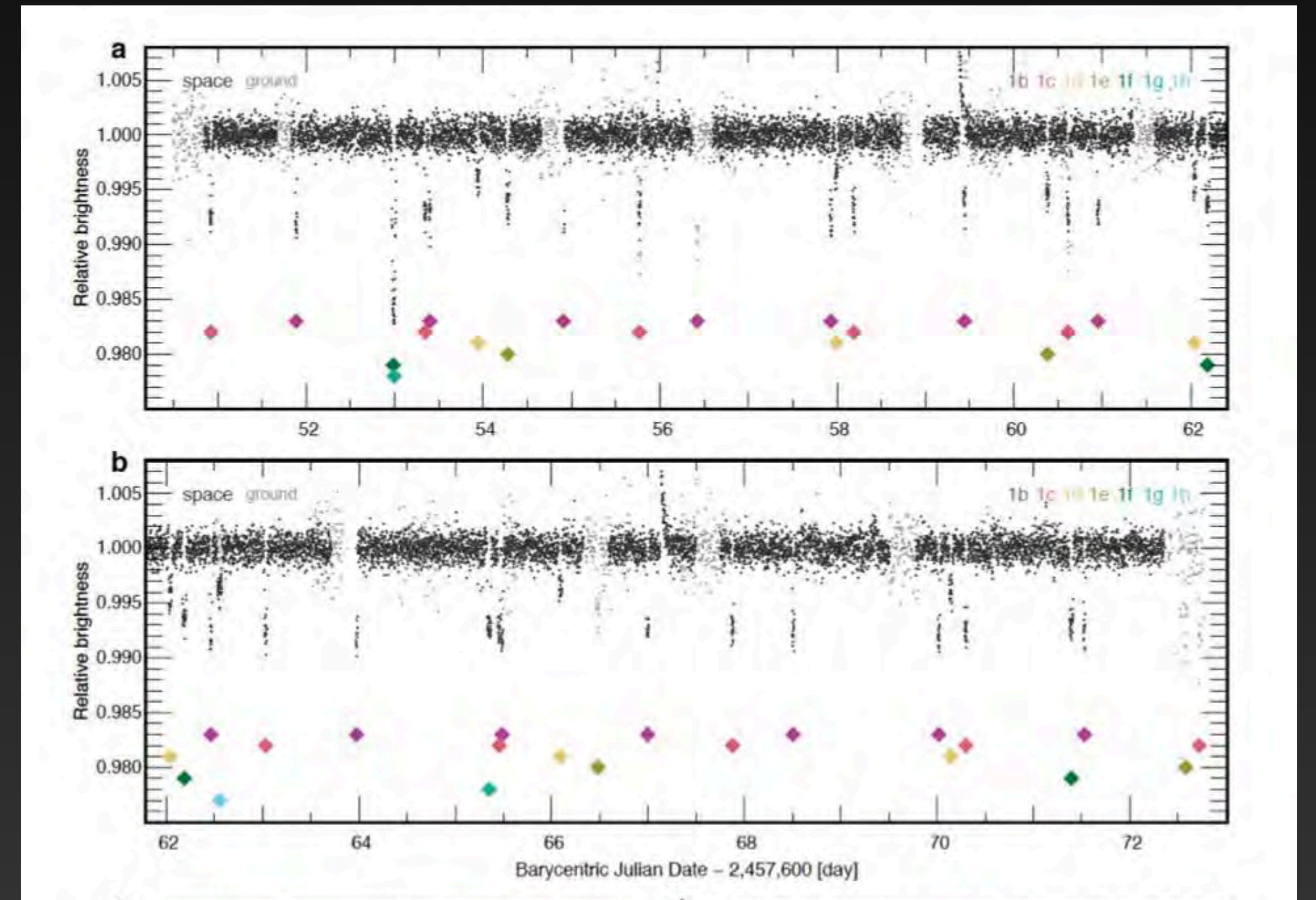
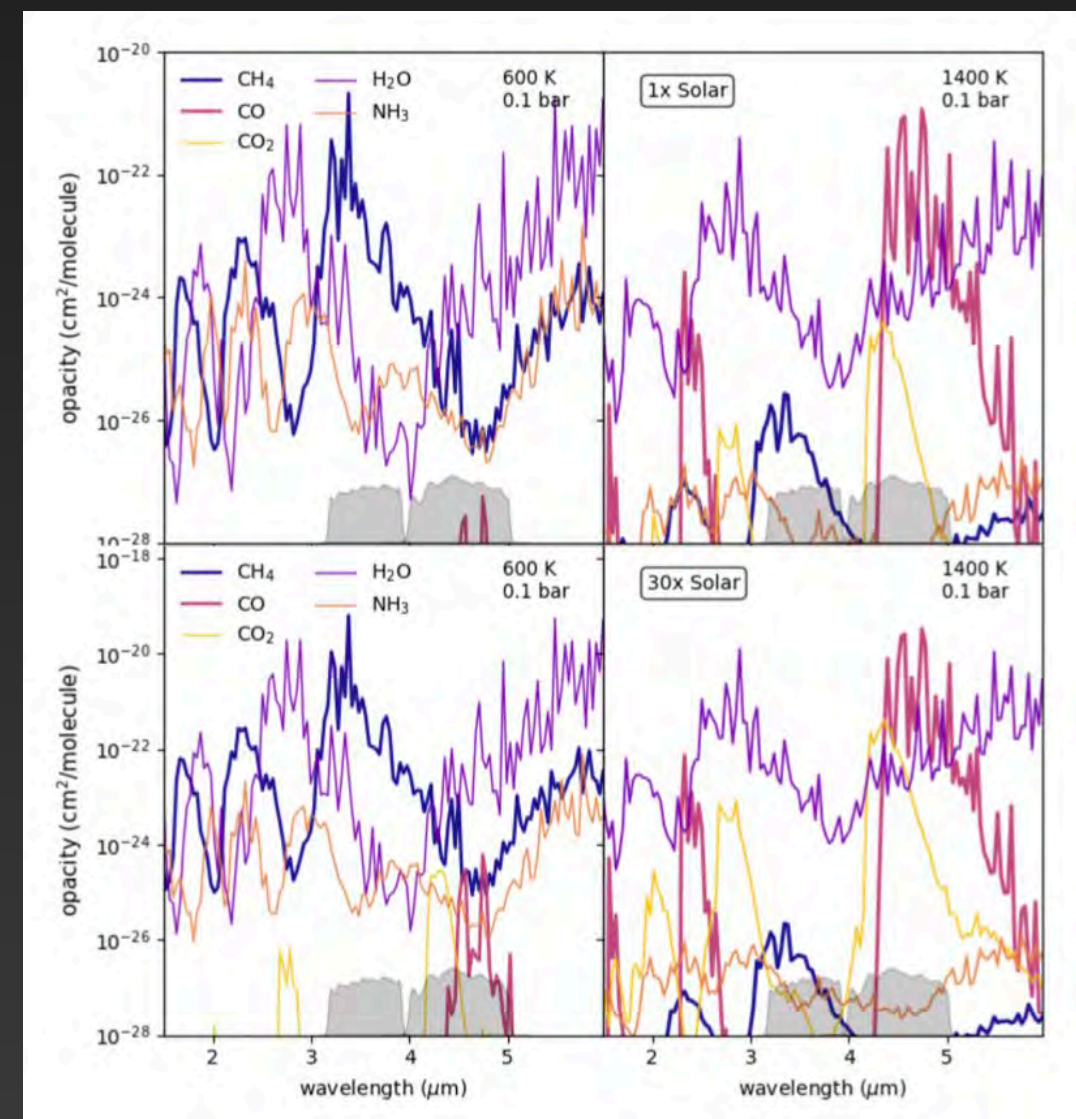
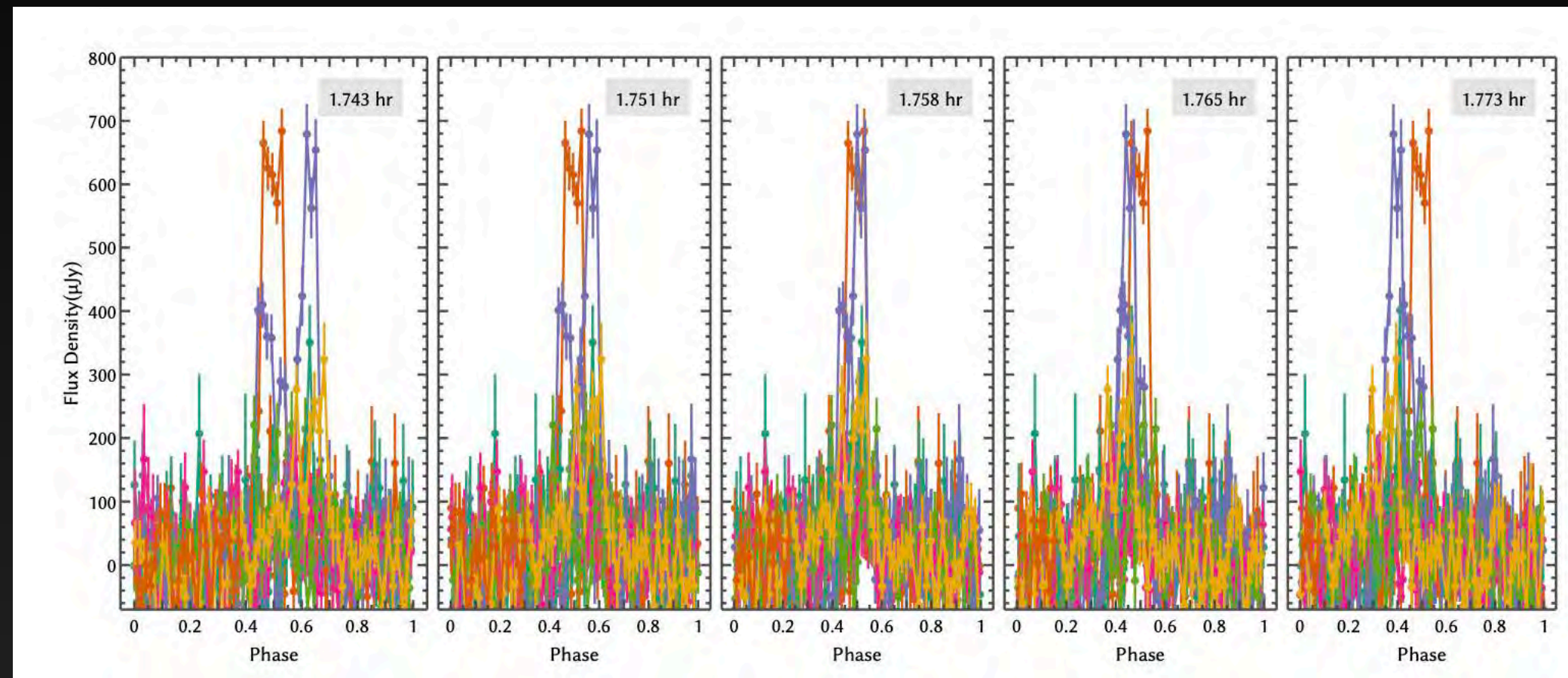
Spitzer GALEX [NEO]WISE Herschel NuSTAR Kepler ZTF LIGO EHT (+...)



# Often data can tell the story...



# ... but sometimes it needs help.



# Astronomy Illustrations

Inspire

# Astronomy Illustrations

Inspire

Inform

# “Early Work”



Robert Hurt  
Acrylic/Airbrush  
**Untitled Galaxy** (circa 1979)



# Galaxies of the '70's



M95 © Anglo-Australian Observatory  
Photo by David Malin



© Malin/Caltech

# Power of Visualizations



M95 © Anglo-Australian  
Photo by David Malin



© Malin/Caltech



Spitzer Space Telescope  
Infrared Light  
**Messier 81** (2019)

**Visualizations can deeply affect our  
mental geography of the universe.**

**~~Even~~ *Especially* Artwork.**

# What is “Communications”?

Education  
*Classrooms*

Informal Ed  
*Museums*

Communications  
*News Media*

# What is “Communications”?

Education  
*Classrooms*

Informal Ed  
*Museums*

Communications  
*News Media*

**Pre-Arranged**  
*Facilitated*

***Audience***

**Compete for  
Attention**

# Visualizations for Communication

Grab Attention

Illustrate a  
Basic Concept

Lead Audience  
to Article

iPad 9:58 PM 55%

## ASTRONOMY

**INVERSE**  
**These "Wandering Black Holes" Form in the Absolute Saddest Way**  
A new study from Yale University finds some supermassive black holes wander around their respective galaxies. They seem to form as the result of "failed" black hole mergers, which occurs when two of these objects do not totally collide. Future re...

**GIZMODO**  
Tomorrow's Star Map Release Could Revolutionize Our Understanding of Astronomy  
10h ago

**INVERSE**  
This Spacecraft You've Never Heard of Could "Revolutionize Astronomy"  
9h ago

**THEVERGE**  
House bill would regulate bold commercial space missions — but not very closely  
13h ago

**TIME**  
Uranus Smells Terrible. There, We Said it  
12h ago

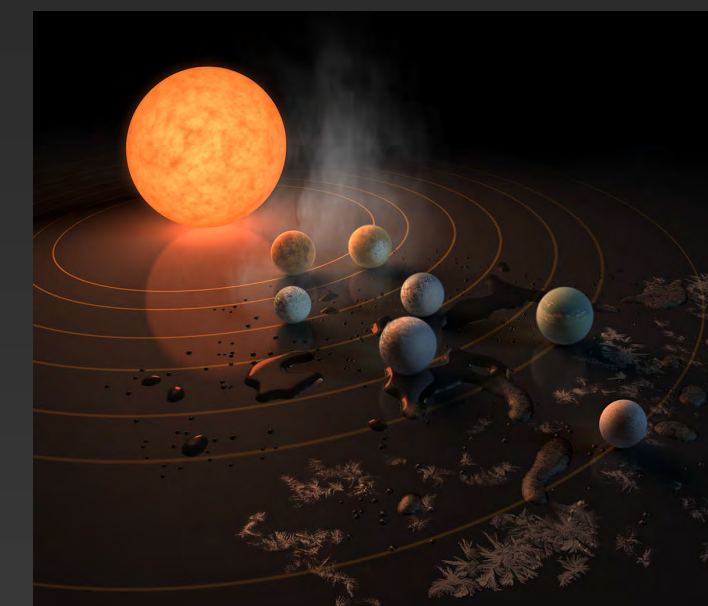
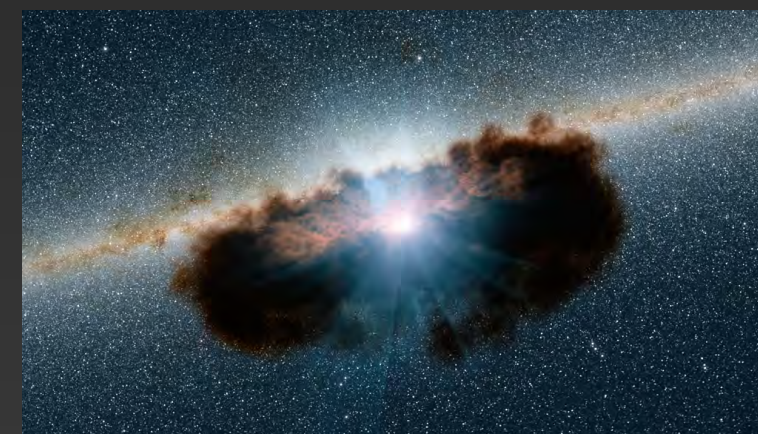
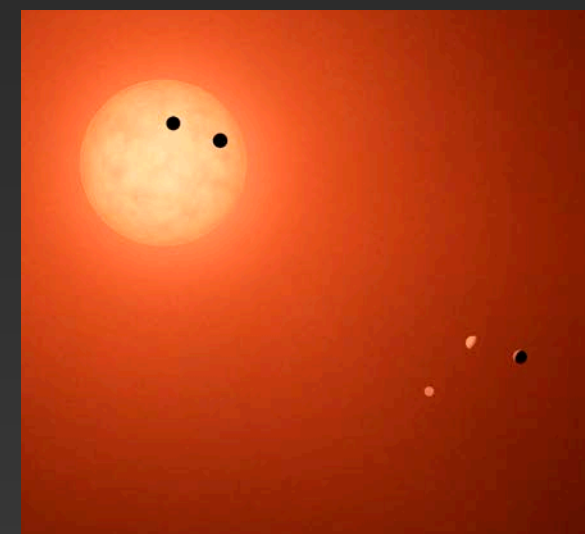
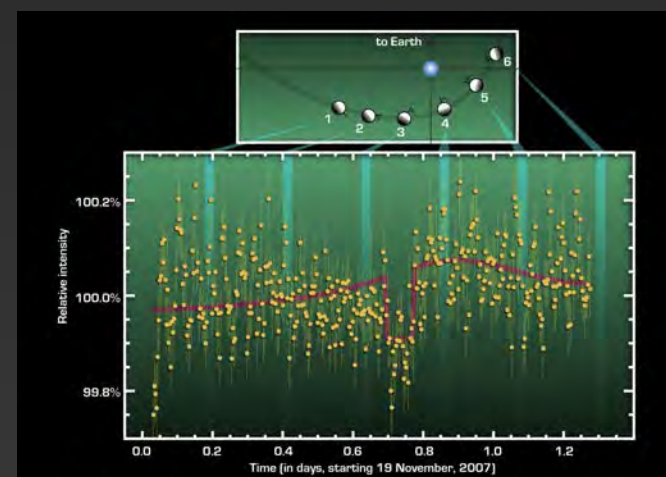
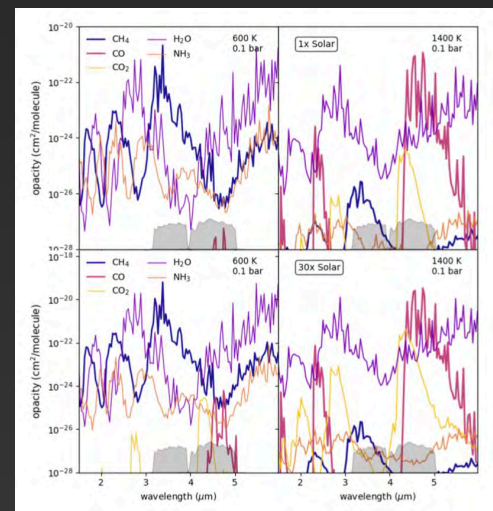
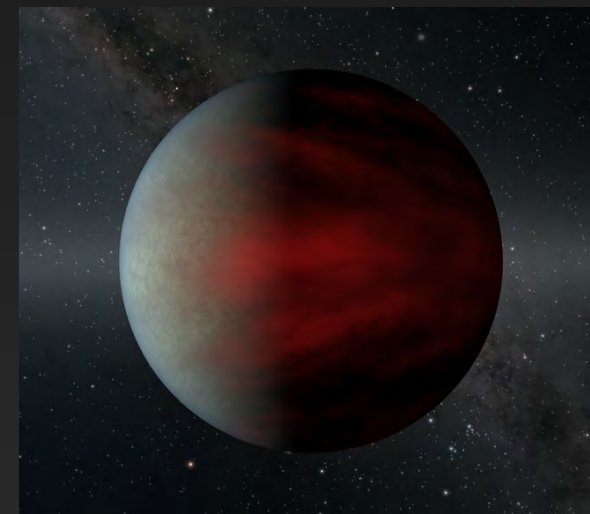
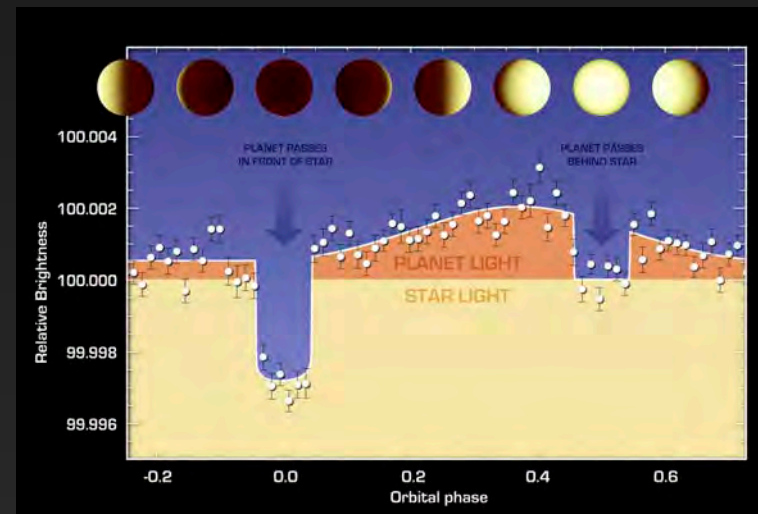
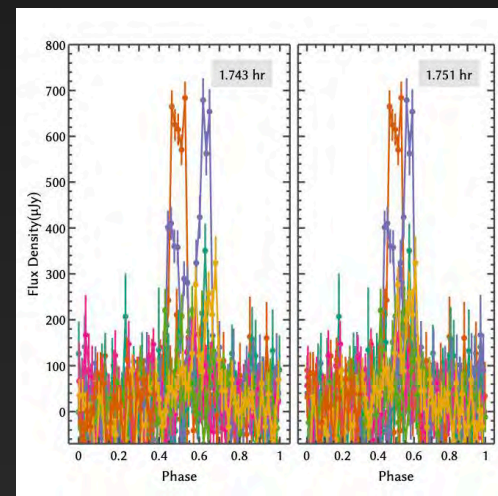
**Newsweek**  
Picture of Jupiter's Great Red Spot Captured by NASA'S Juno Spacecraft

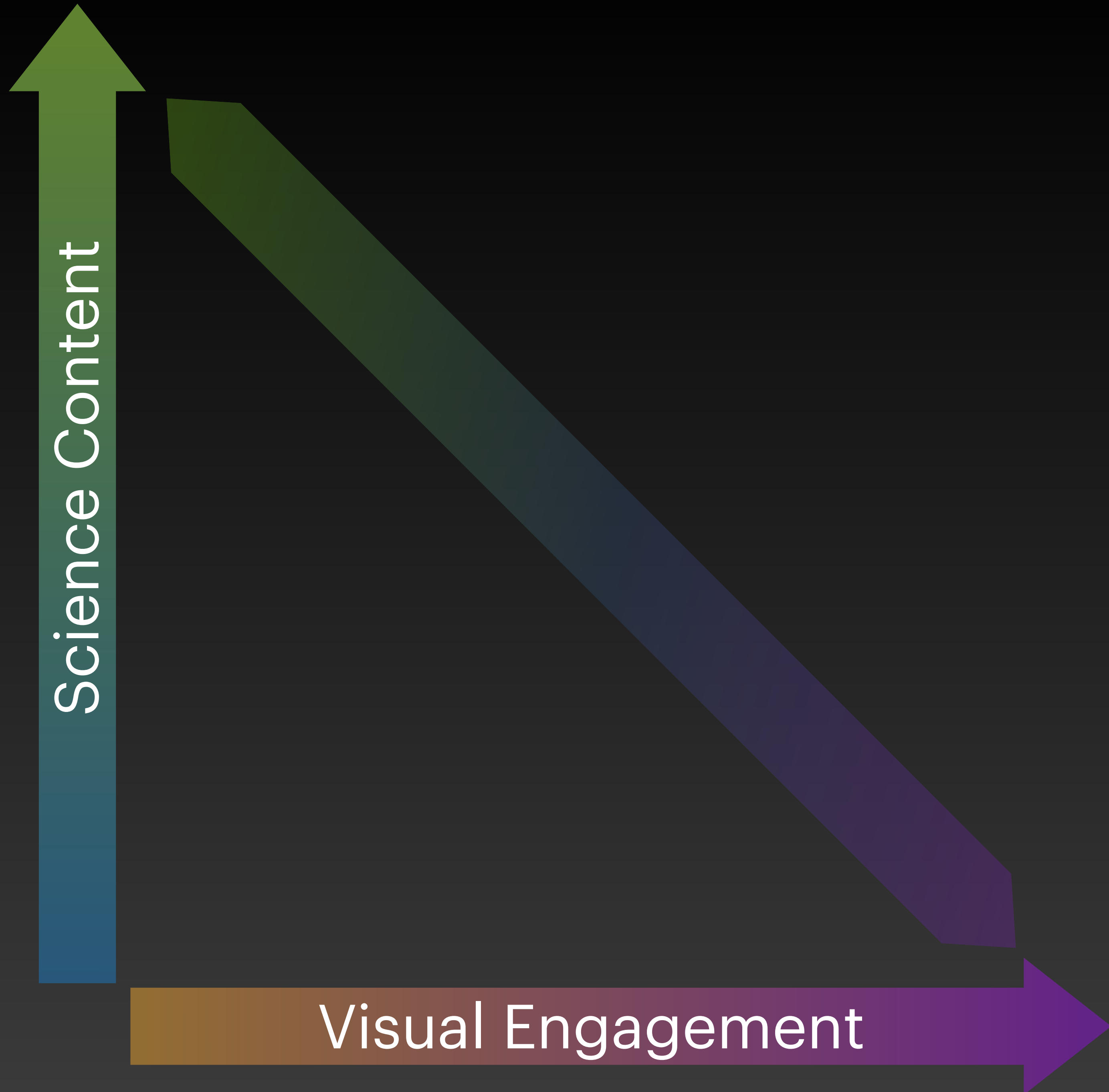
For You Spotlight Following Search Saved

# The Data-Art Continuum

Pure Data

Pure Aesthetics



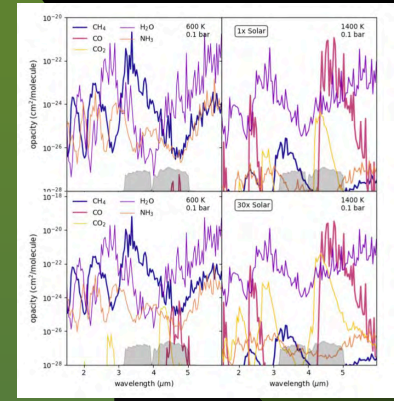


Science Content

Visual Engagement

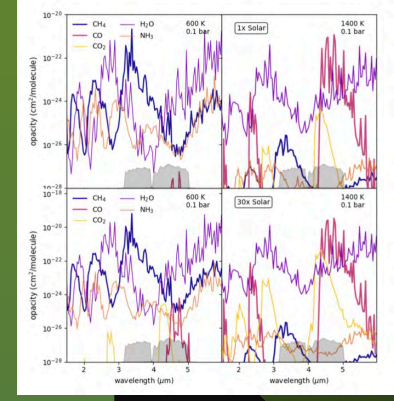


Science Content



Visual Engagement

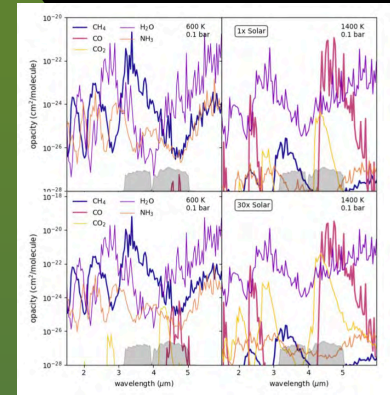
Science Content



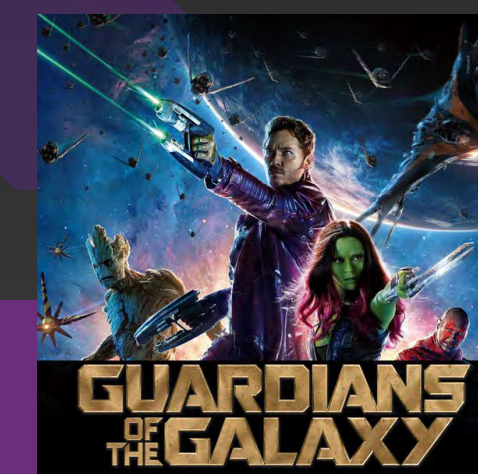
Visual Engagement



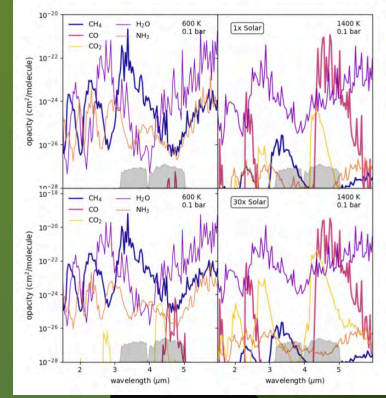
Science Content



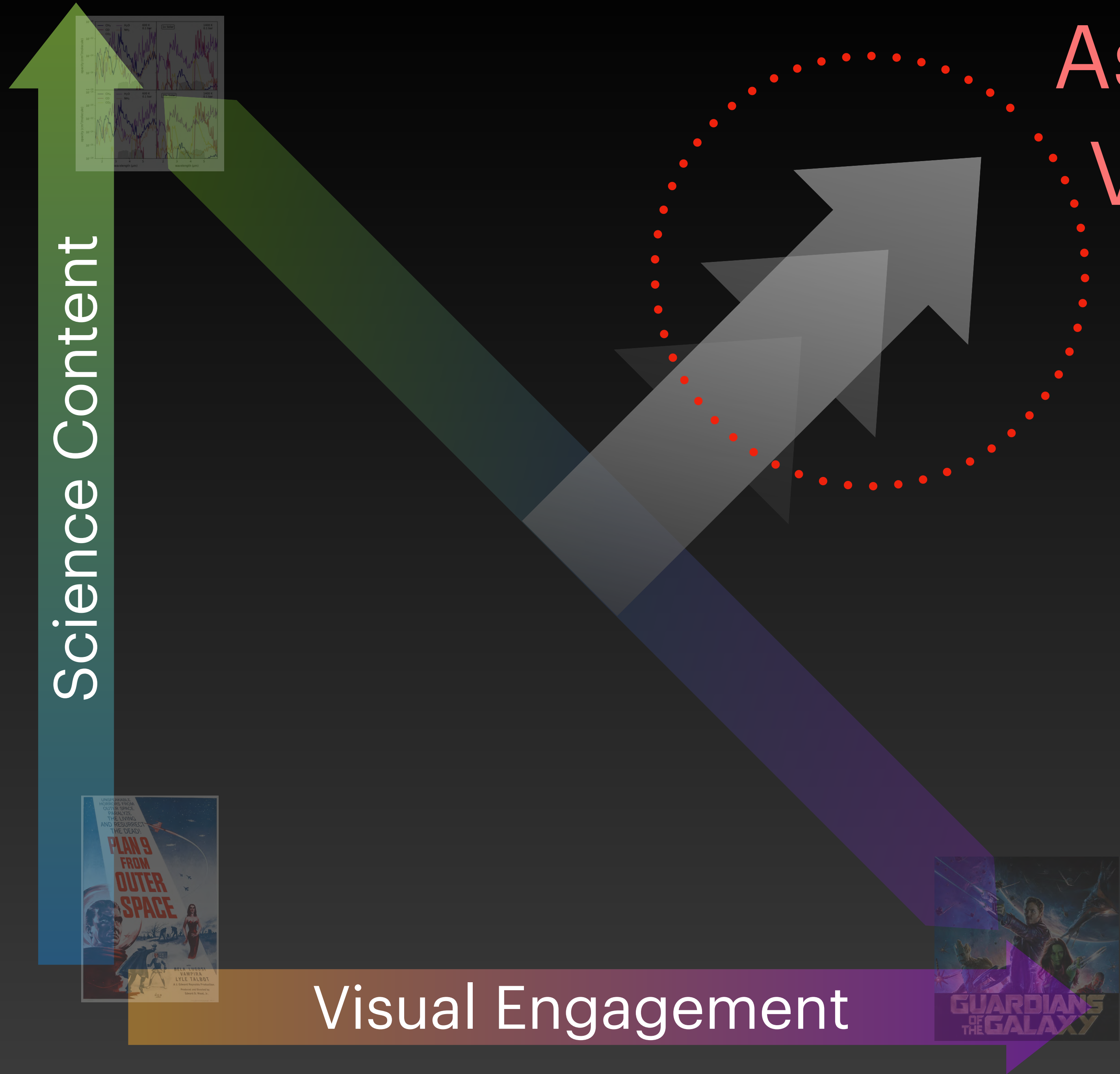
Visual Engagement



Science Content



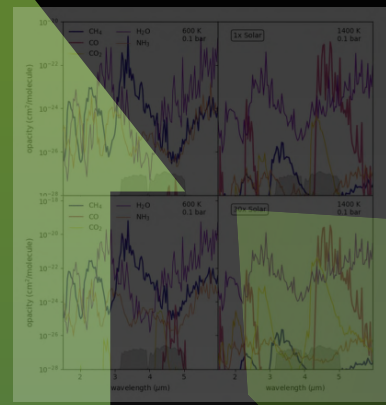
Visual Engagement



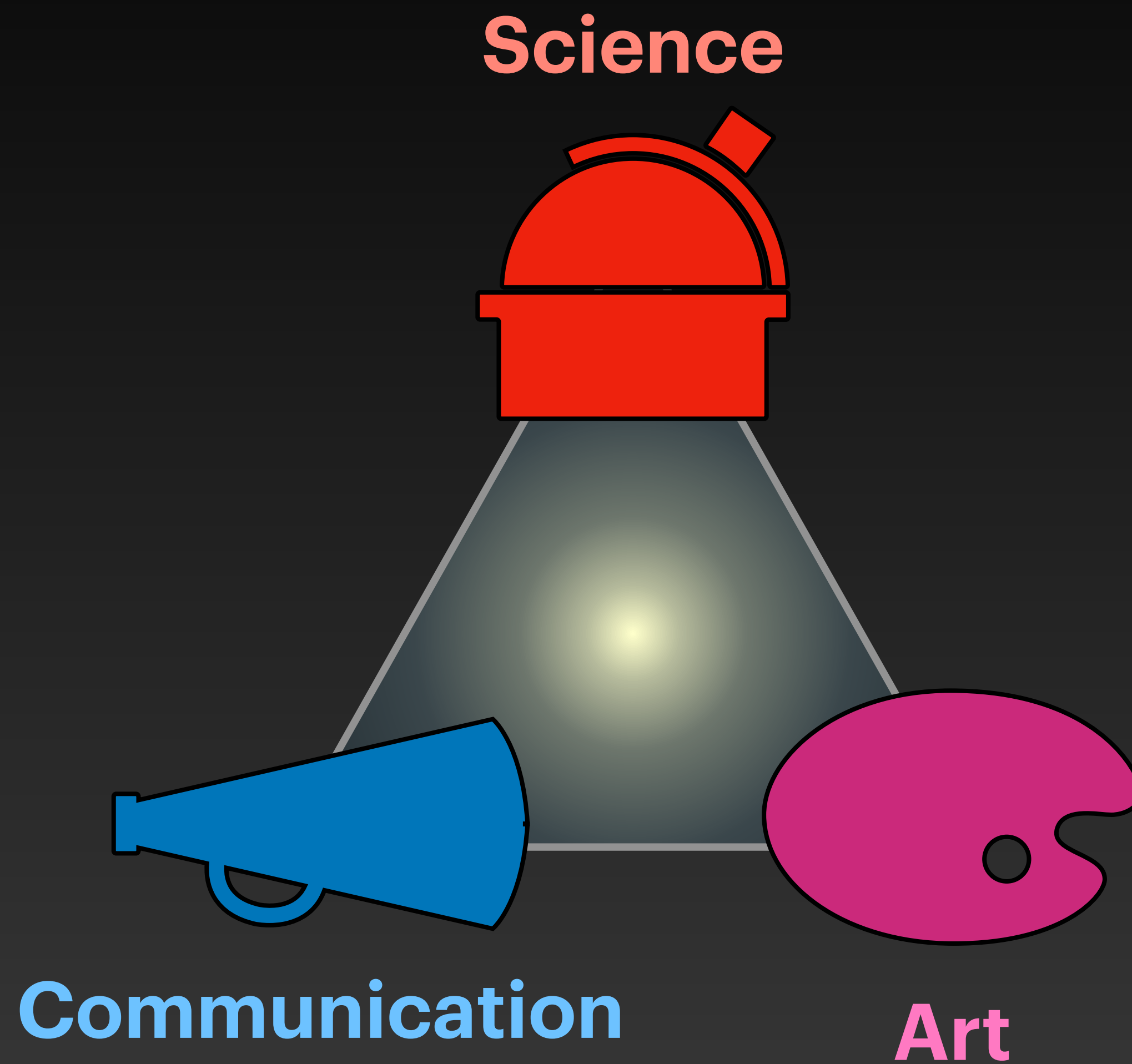
Science Content

Visual Engagement

Astro  
Viz!

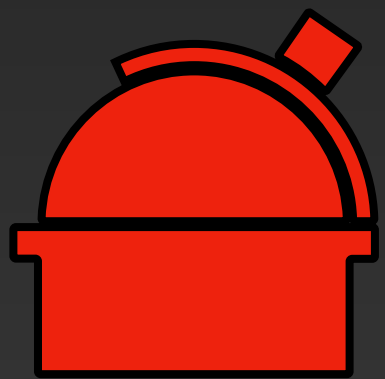


# The AstroViz "Trinity"



# Best Practices Approach

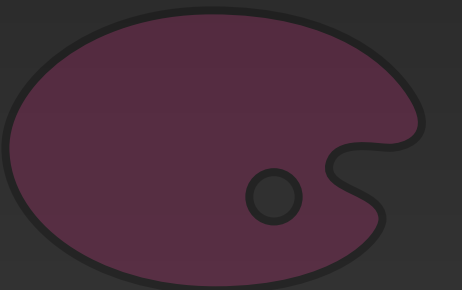
- Topic 1
  - Detail A
  - Detail B
  - Detail C
- Topic 2
  - Detail D
  - Detail E
- Topic 3
  - Detail F
  - Detail G
  - Detail H



**Science**



**Communication**

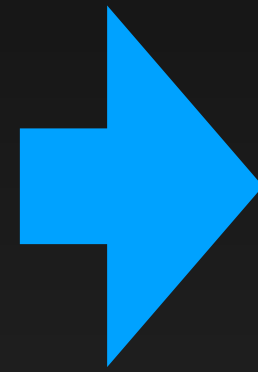


**Art**

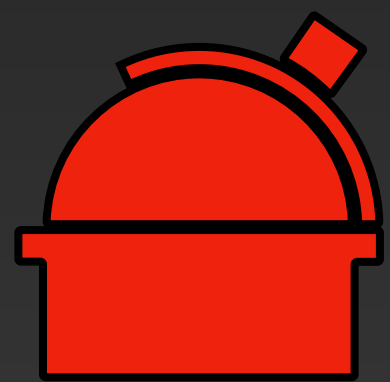
# Best Practices Approach

- Topic 1
  - Detail A
  - Detail B
  - Detail C
- Topic 2
  - Detail D
  - Detail E
- Topic 3
  - Detail F
  - Detail G
  - Detail H

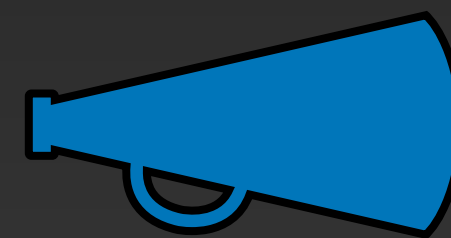
Identify audience,  
Narrow focus,  
Craft narrative



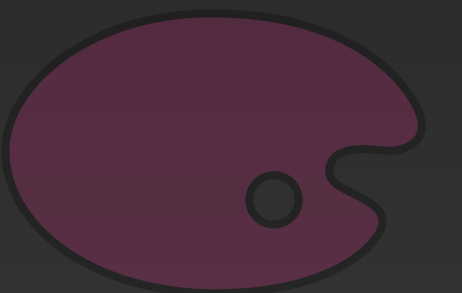
- Topic 1
  - Detail A
  - Detail B
  - Detail C
- Topic 2
  - Detail D
  - Detail E
- Topic 3
  - Detail F
  - Detail G
  - Detail H



Science



Communication



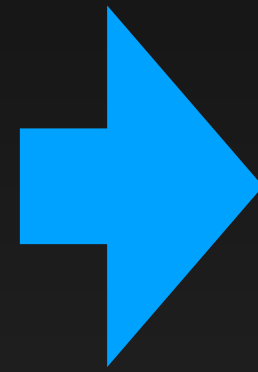
Art



# Best Practices Approach

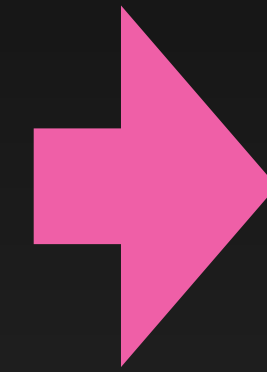
- Topic 1
  - Detail A
  - Detail B
  - Detail C
- Topic 2
  - Detail D
  - Detail E
- Topic 3
  - Detail F
  - Detail G
  - Detail H

Identify audience,  
Narrow focus,  
Craft narrative

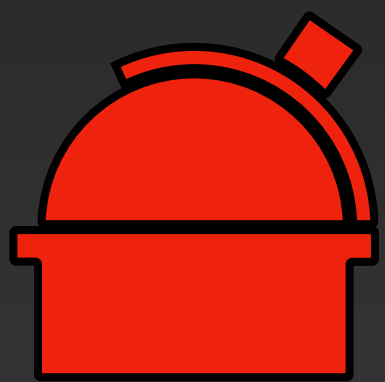


- Topic 1
  - Detail A
  - Detail B
  - Detail C
- Topic 2
  - Detail D
  - Detail E
- Topic 3
  - Detail F
  - Detail G
  - Detail H

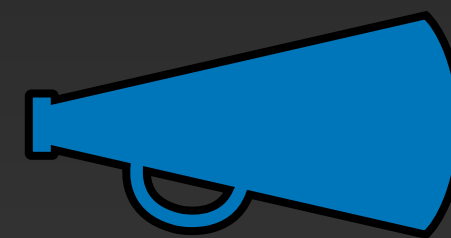
Identify visual  
concepts,  
Visual appeal



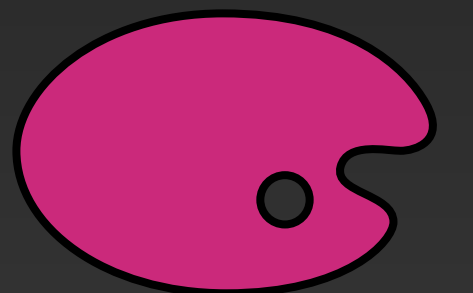
- Topic 1
  - Detail A
  - Detail B
  - Detail C
- Topic 2
  - Detail D
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- Topic 3
  - Detail F
  - Detail G
  - Detail H



Science



Communication

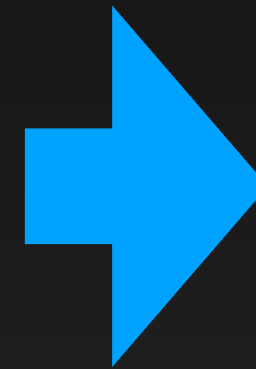


Art

# Best Practices Approach

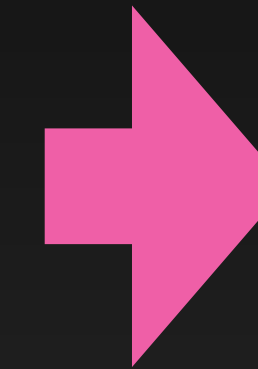
- Topic 1
  - Detail A
  - Detail B
  - Detail C
- Topic 2
  - Detail D
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  - Detail F
  - Detail G
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Identify audience,  
Narrow focus,  
Craft narrative



- Topic 1
  - Detail A
  - Detail B
  - Detail C
- Topic 2
  - Detail D
  - Detail E
- Topic 3
  - Detail F
  - Detail G
  - Detail H

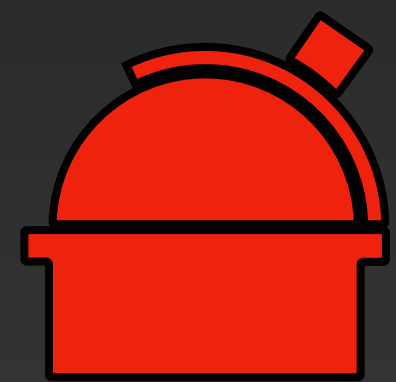
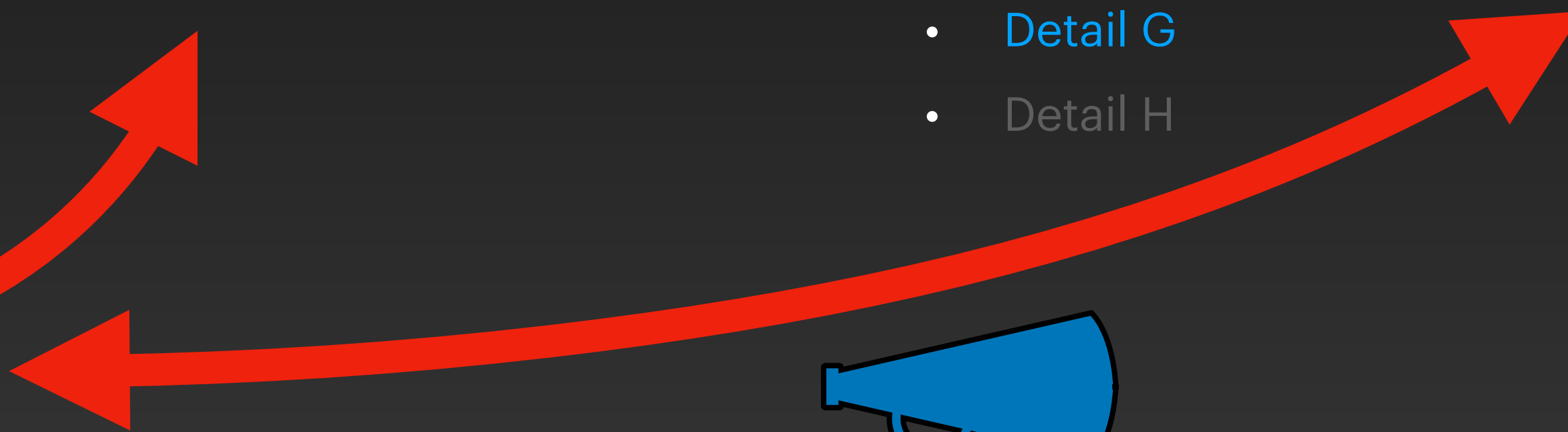
Identify visual  
concepts,  
Visual appeal



- Topic 1
  - Detail A
  - Detail B
  - Detail C
- Topic 2
  - Detail D
  - Detail E
- Topic 3
  - Detail F
  - Detail G
  - Detail H

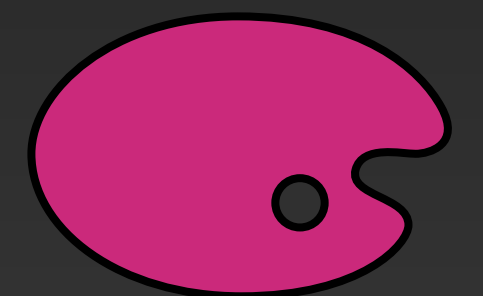
Validate narrative

Validate visuals



Science

Communication



Art

# Visualizing the Visualization Process

Known Facts



**Known Facts**

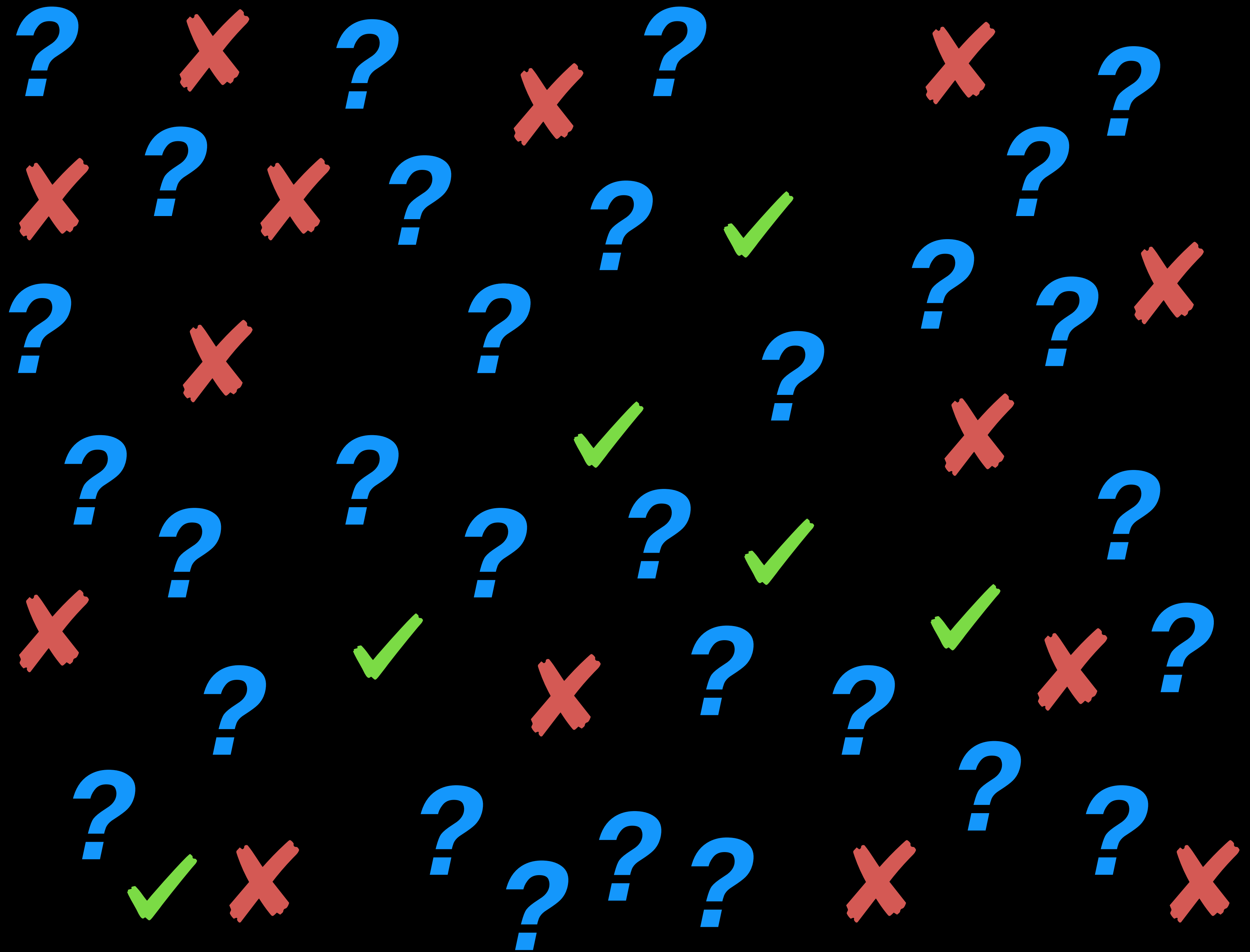
**Known  
Falsehoods**



**Known Facts**

**Known  
Falsehoods**

**Possibilities**

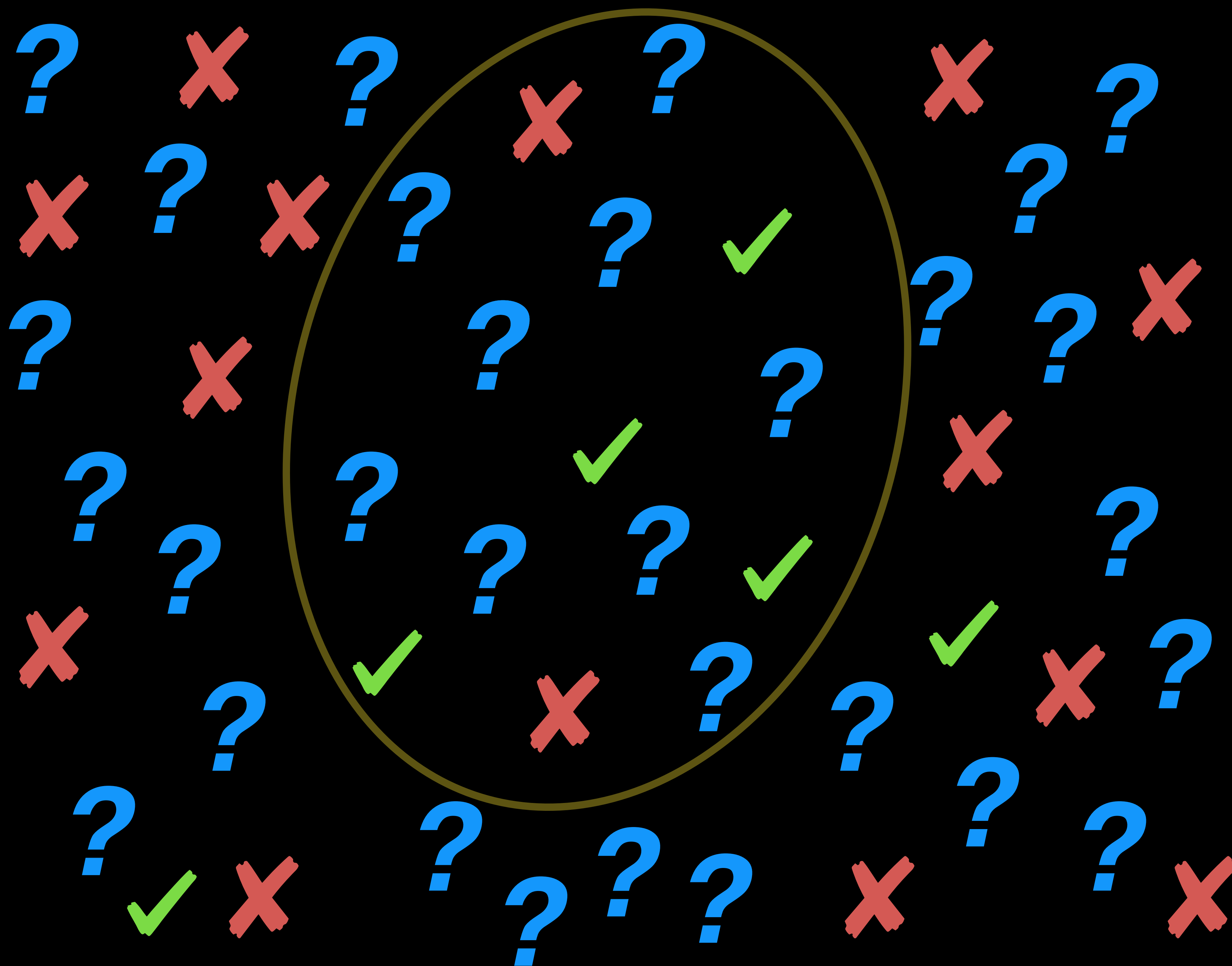


**Known Facts**

**Known  
Falsehoods**

**Possibilities**

*Sometimes we include  
falsehoods in the  
service of clarity!  
(e.g. exaggerated scale)*

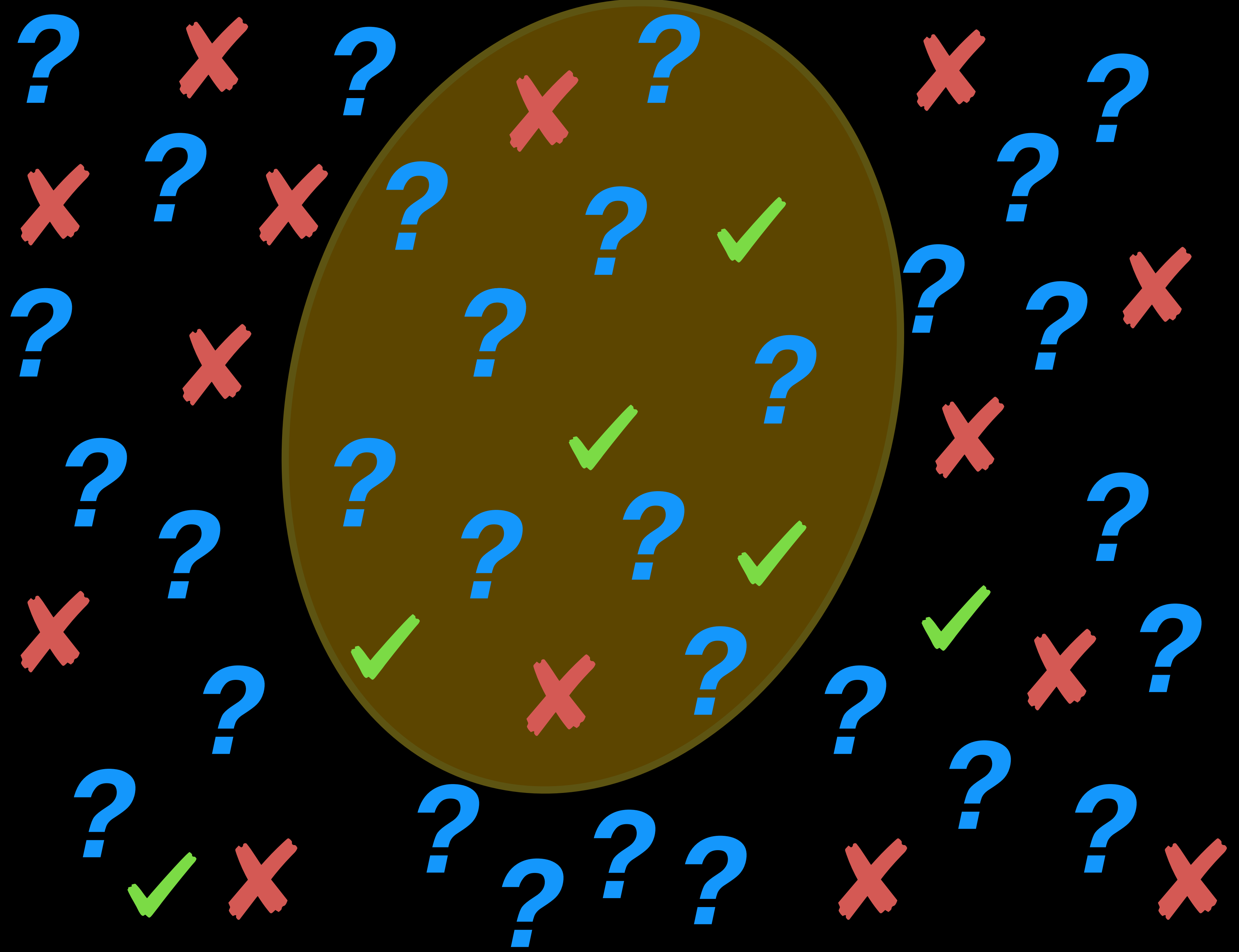


# Art

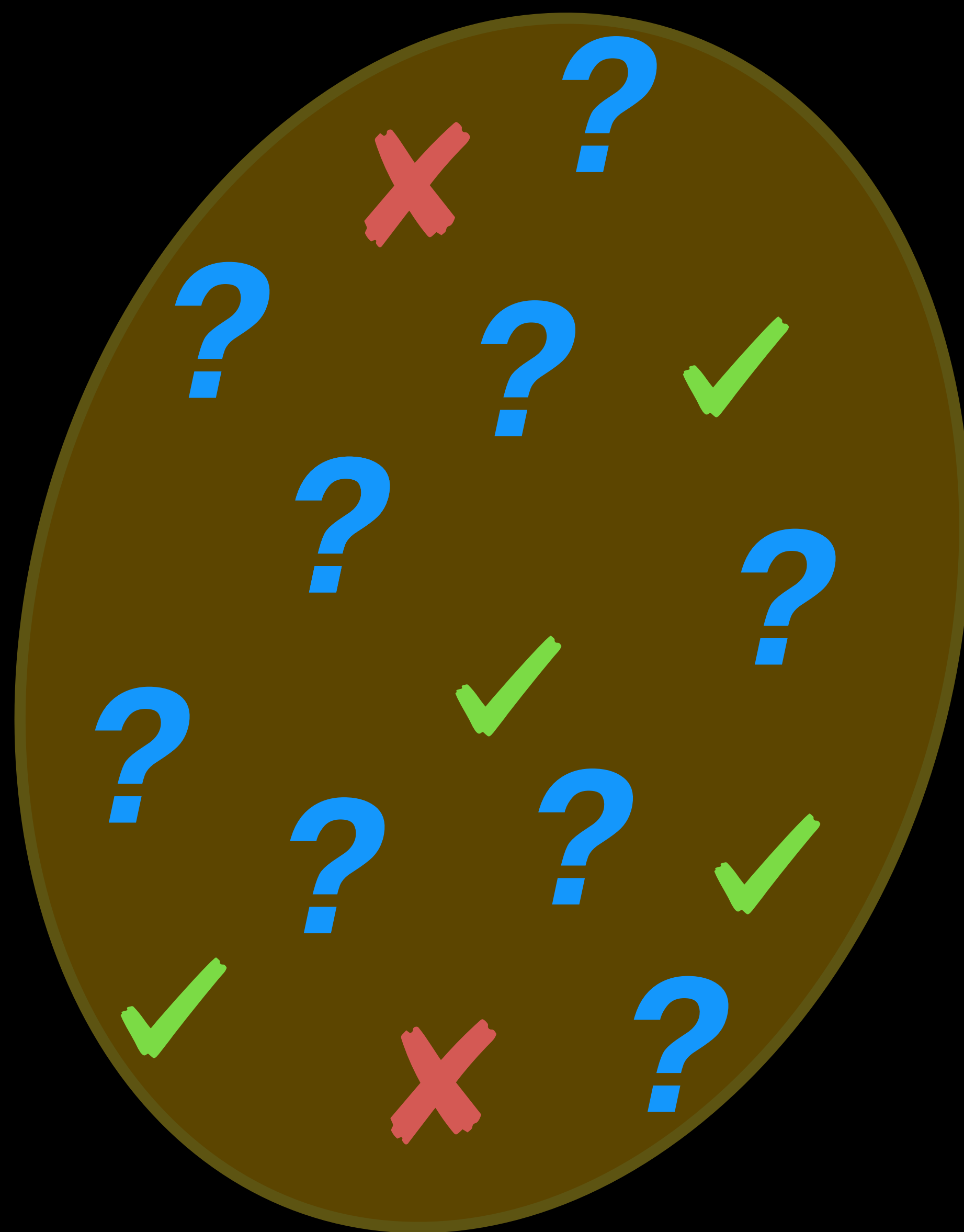
Known Facts

Known  
Falsehoods

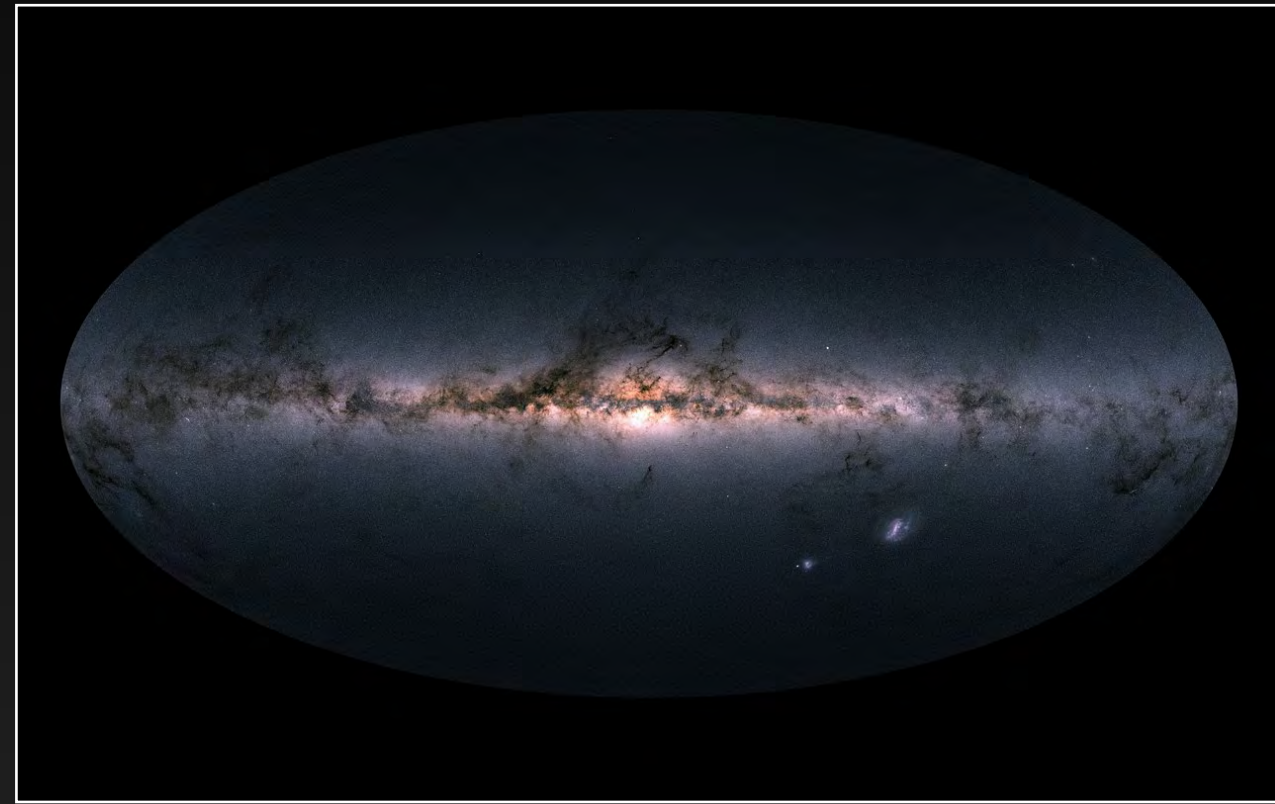
Possibilities



**Art +**  
**Possibilities**  
**=**  
***Hypotheses***



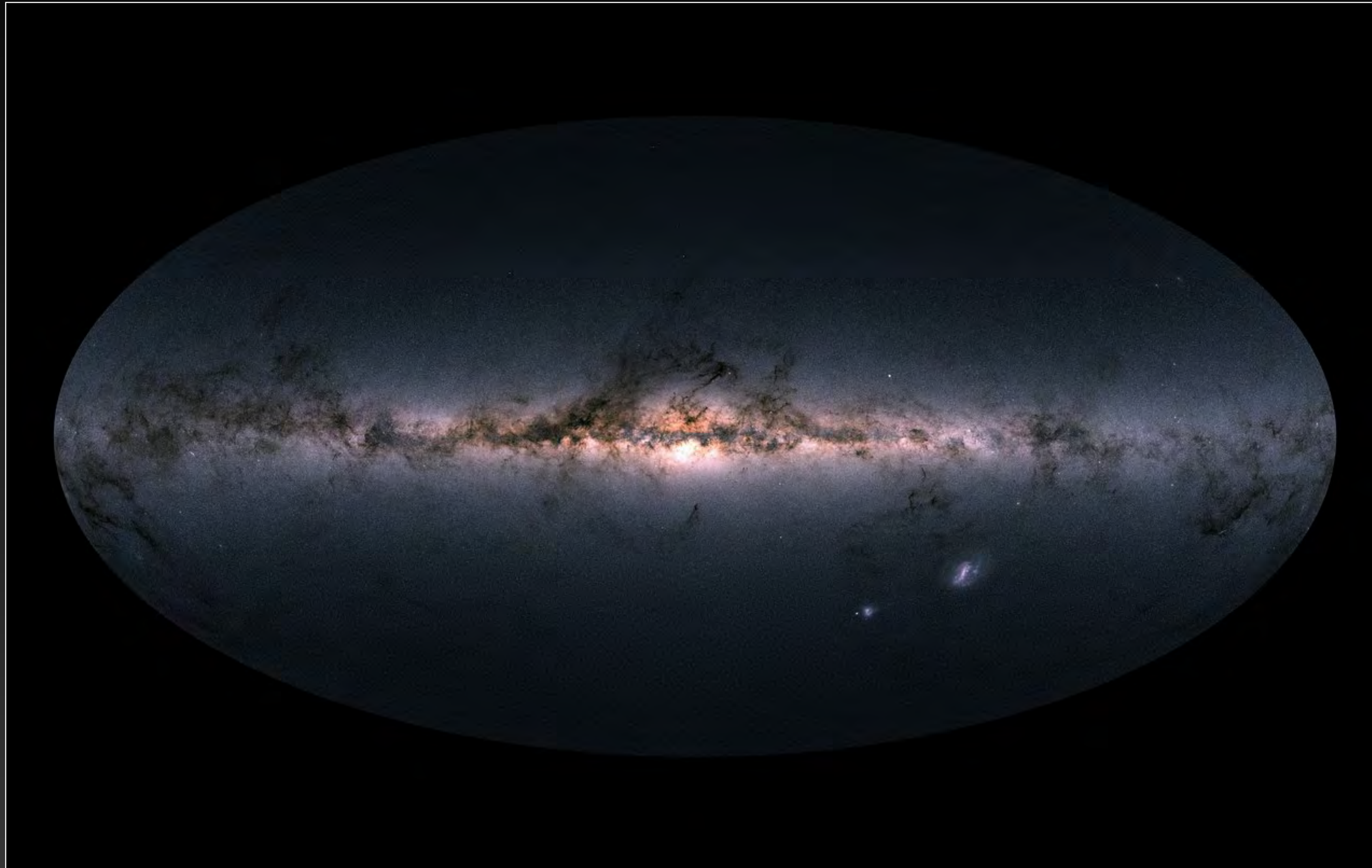




*Case Study*

# **The Milky Way**

# Why Do We Need to Illustrate the Milky Way?

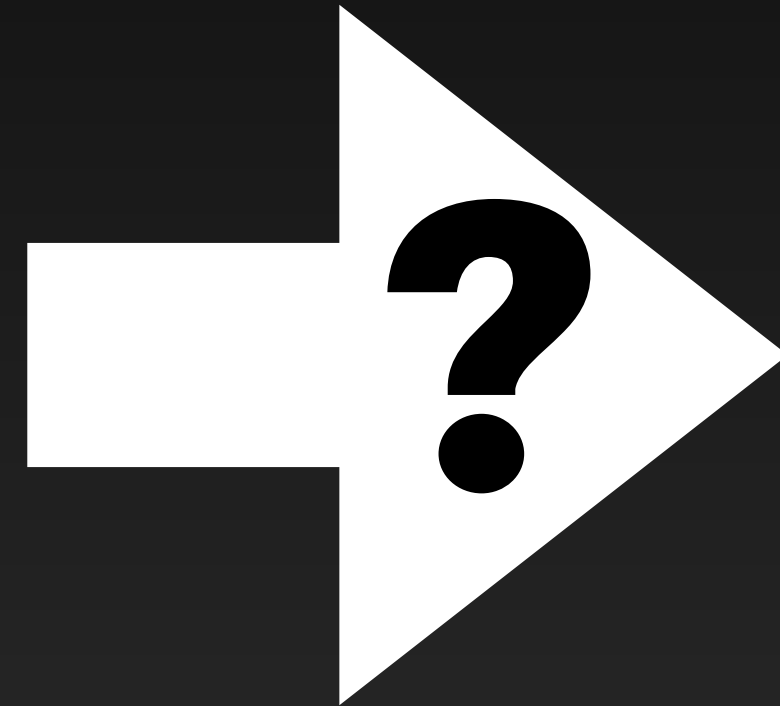




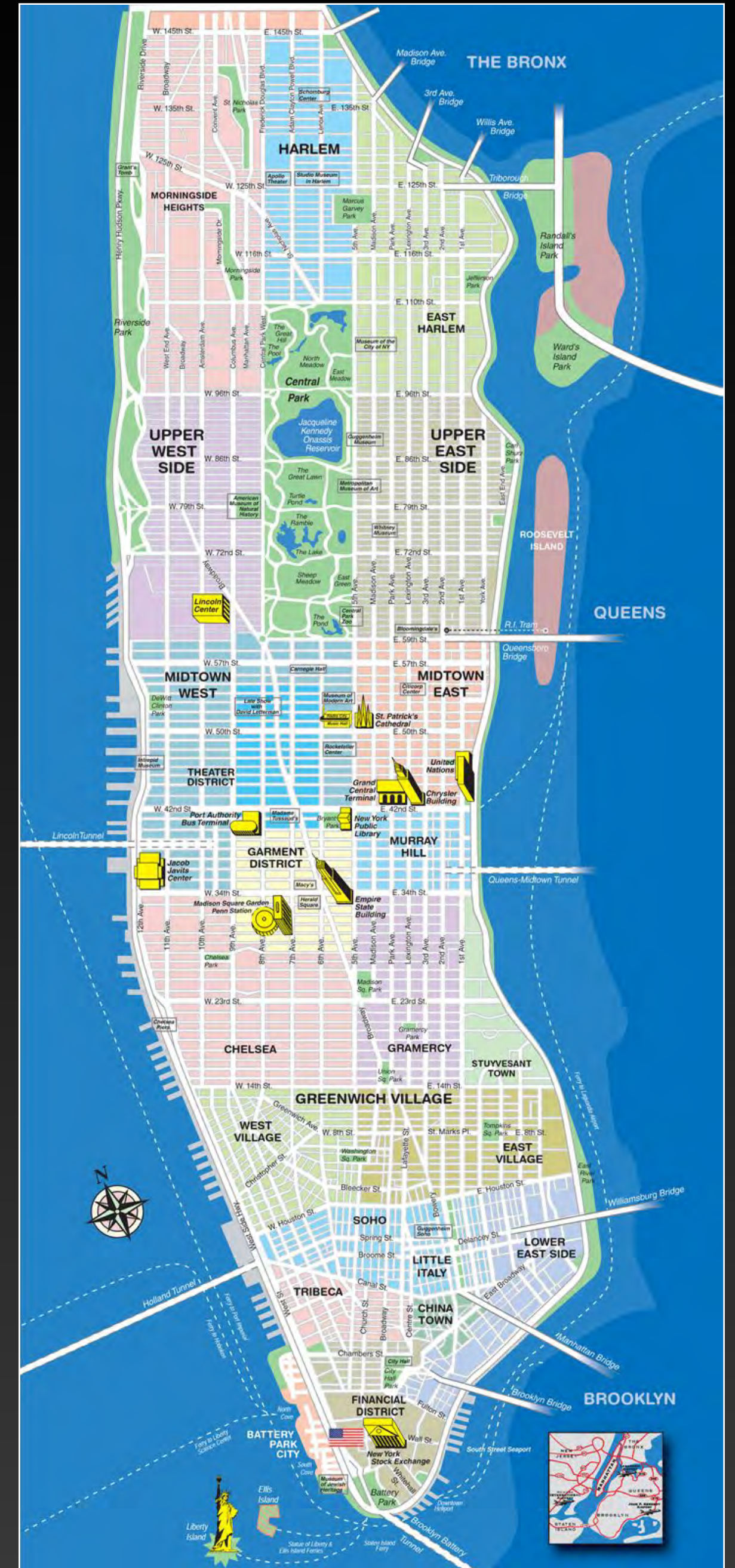
Times Square, NYC

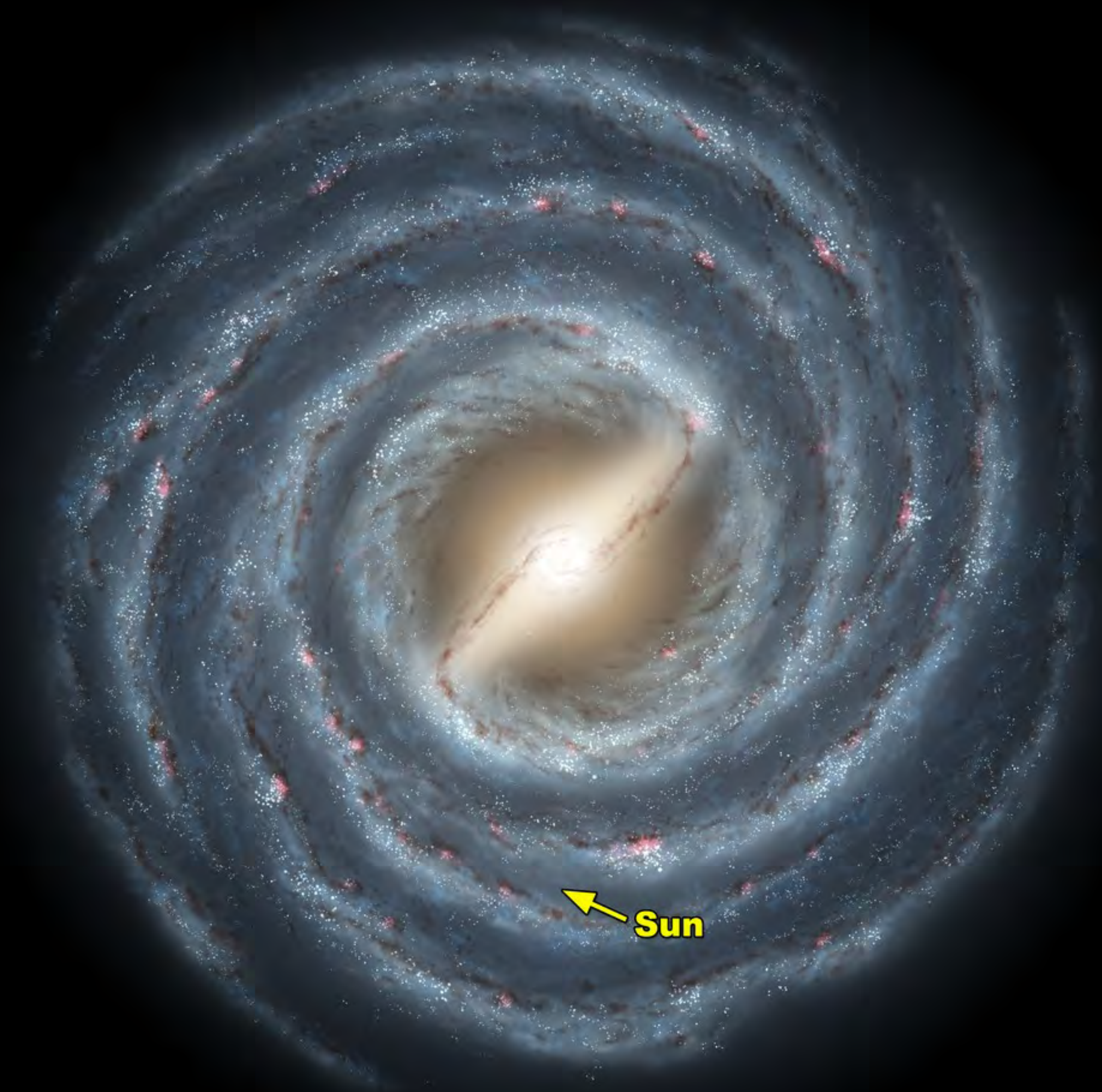


Times Square, NYC



Map of  
Manhattan

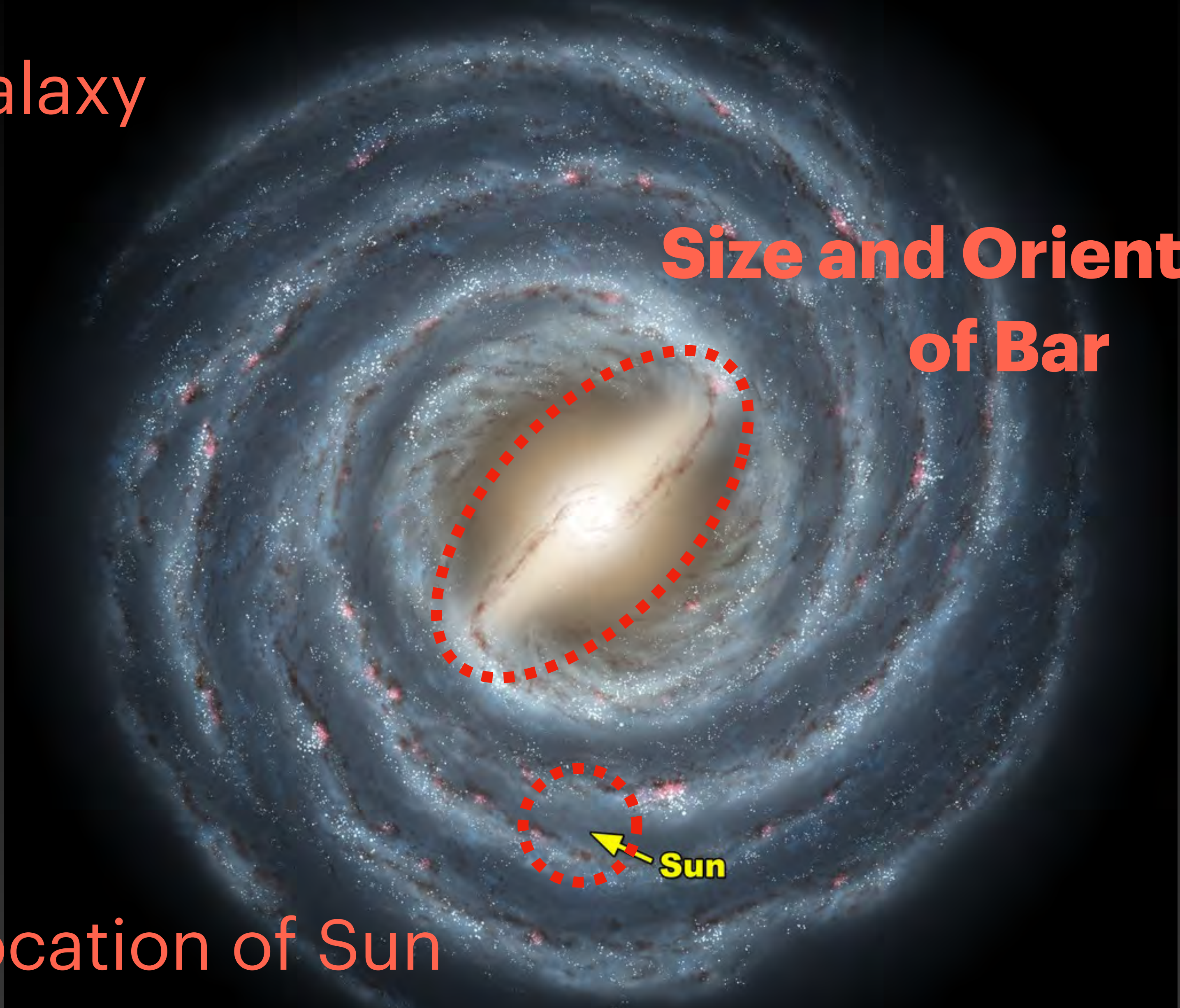




Sun

Spitzer Release  
2005

# Spiral Galaxy



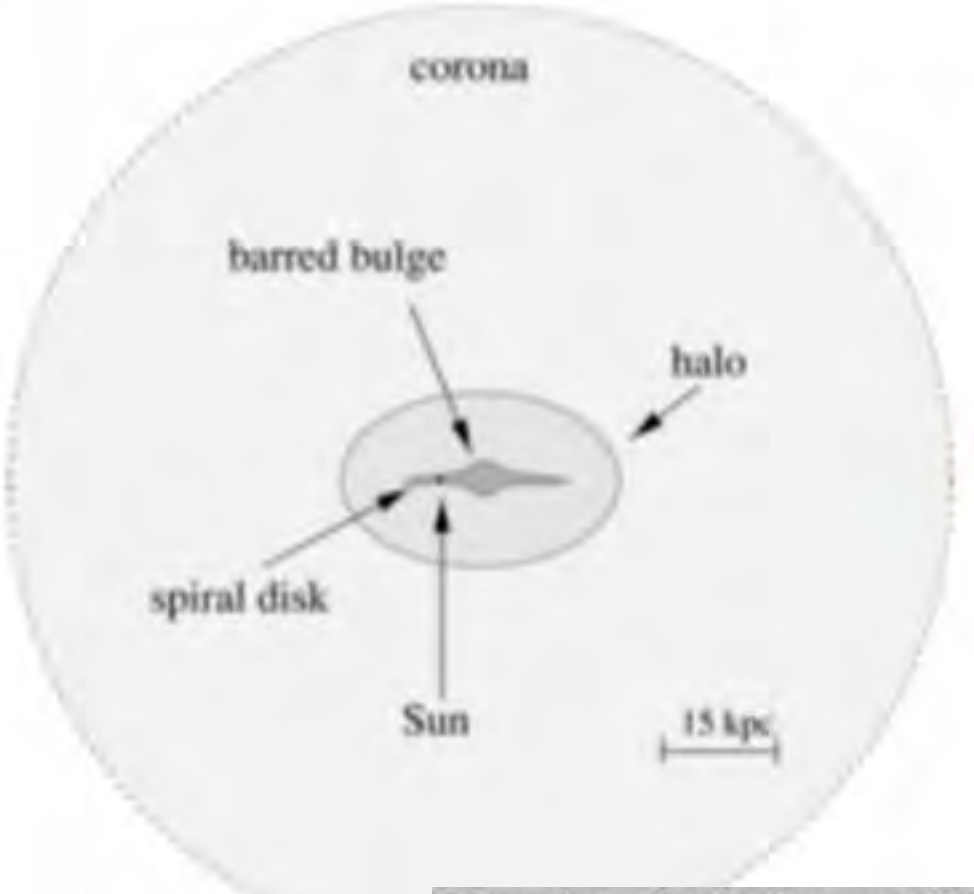
**Size and Orientation  
of Bar**

**Location of Sun**

Spitzer Release  
2005

Figure 1 - uploaded by Cetin Can Evirgen  
Content may be subject to copyright.

Download View publication



1: (a) The Milky Way Galaxy viewed from above. (b) A cross-sectional diagram of the Milky Way (Englmaier, 2002).

wayfair

Find anything home...

Furniture Outdoor Bedding & Bath Rugs Décor & Pillows Organization Lighting Kitchen Baby & Kids Home Improvement Appliances Pet Holiday Sale

### A View Of Our Own Milky Way Galaxy And Its Central Bar As It Might Appear If Viewed From Above by Stocktrek Images - Unframed Graphic Art on...

By East Urban Home

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\$57.99 ~~\$142.00~~ 59% Off

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Matte Color: Select Matte Color

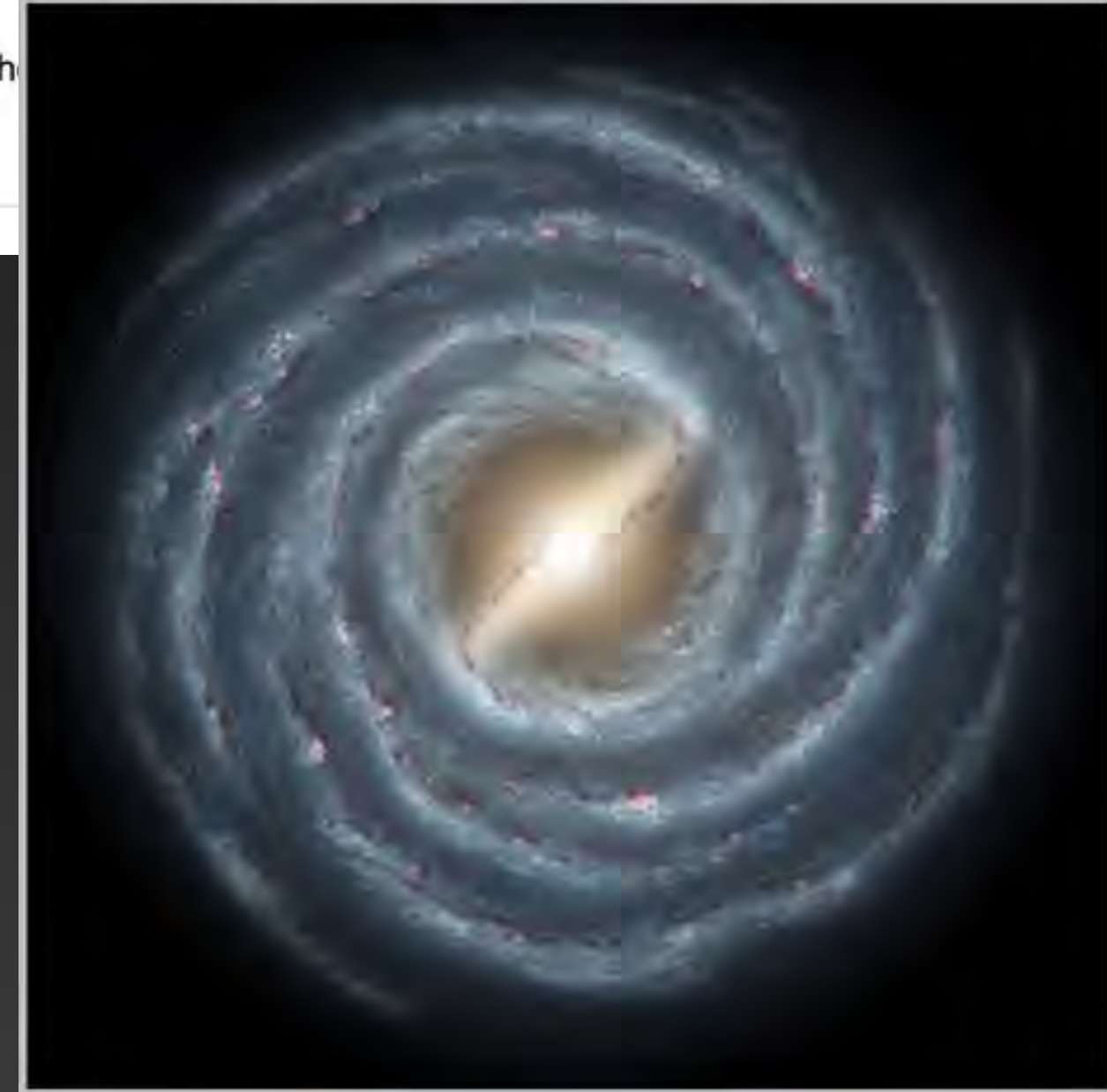
Size: 12" H x 12" W x 1.5" D

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See Full Details

\$40 OFF your qualifying first order of \$250+1 with a Wayfair credit card

#### Mapping of spiral arms of the Milky Way:



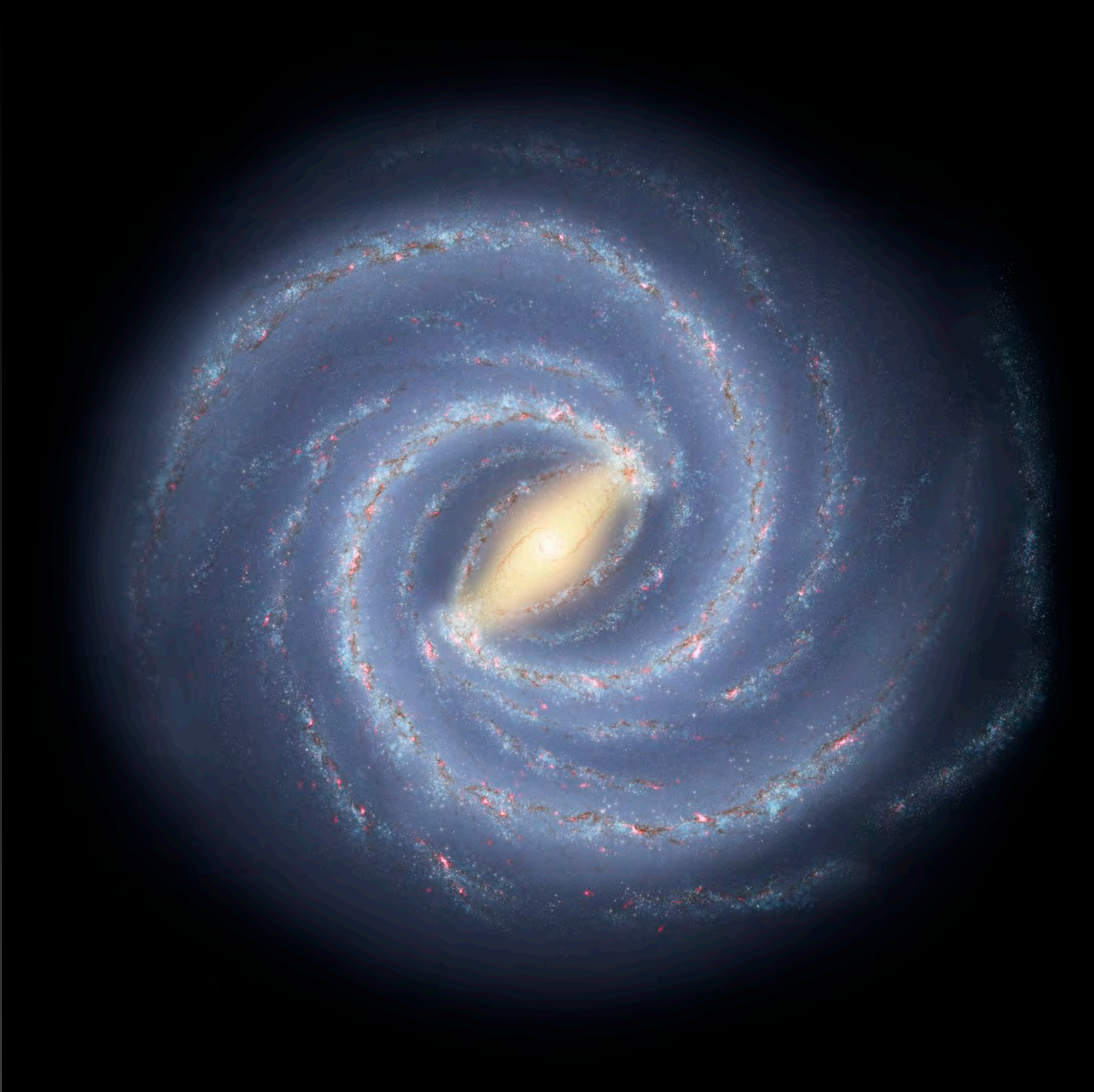
A map of the Milky Way deduced from spiral arm tracers is to the left. Spiral arms can be located with 21-cm line radiation, HII regions, O and B stars.

In the Milky Way, visible light tracers like HII regions or O and B stars can only locate nearby spiral arms but dust prevents using these tracers on a wide scale in the Galaxy.

21-cm line radiation from atomic hydrogen is at such a long wavelength that it can penetrate dust and delineate arms on the other side of the galaxy. Because it is an emission line, it can be used to measure radial velocities. The velocities can be used to determine where along the line of sight the gas lies that is producing the line -- for example, the parts of the galaxy closest to the center are rotating around the center at specific velocities set by the gravitational field -- analogous to how the inner planets in the Solar System orbit the Sun at specific speeds and with specific periods given by Kepler's Laws.

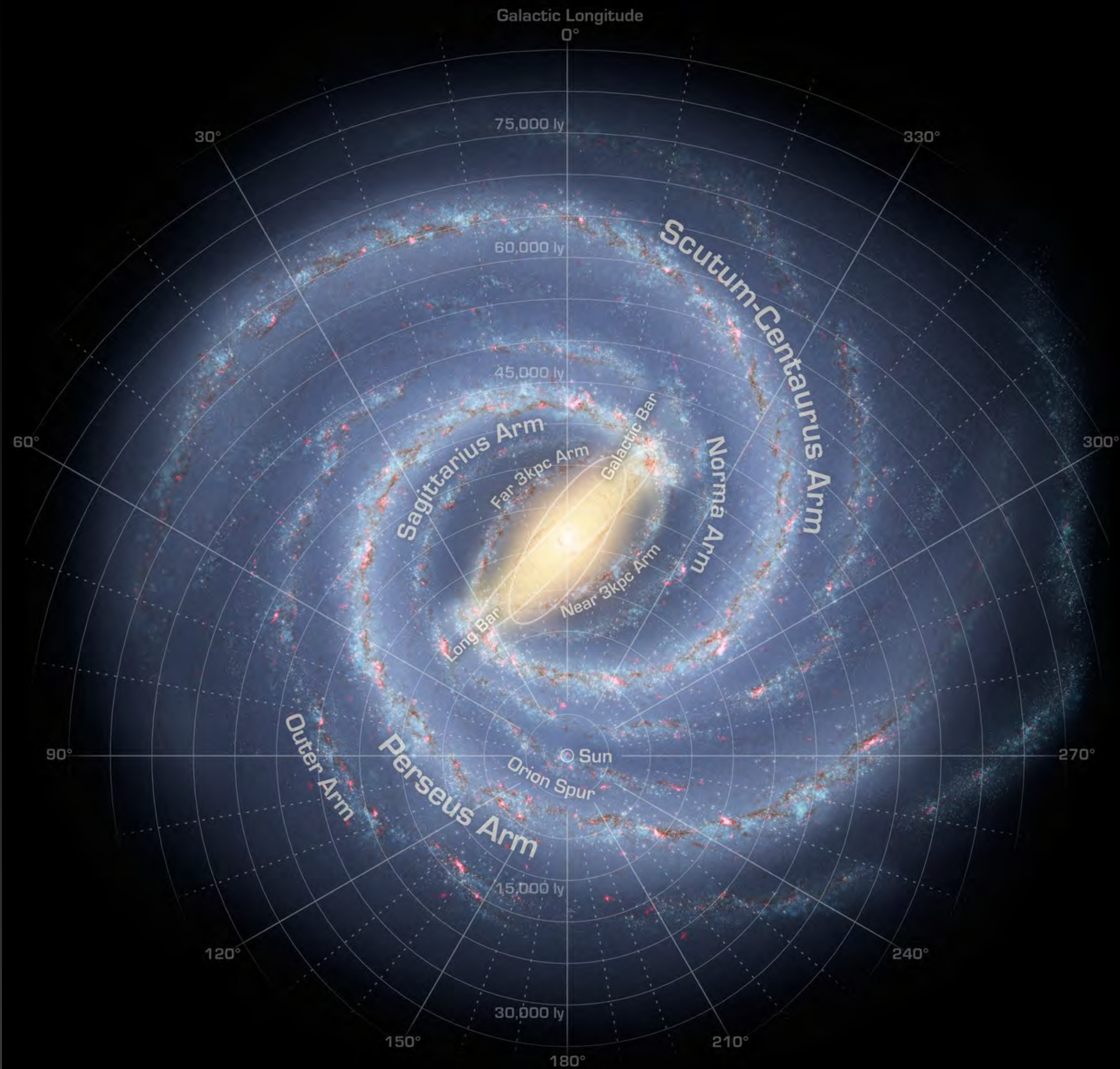
From <http://antwrp.gsfc.nasa.gov/apod/ap050825.html>,  
Astronomy Picture of the Day, R. Hurt, Glimpse Team

# It showed up EVERYWHERE...



Spitzer Release/  
AAS Workshop  
2008

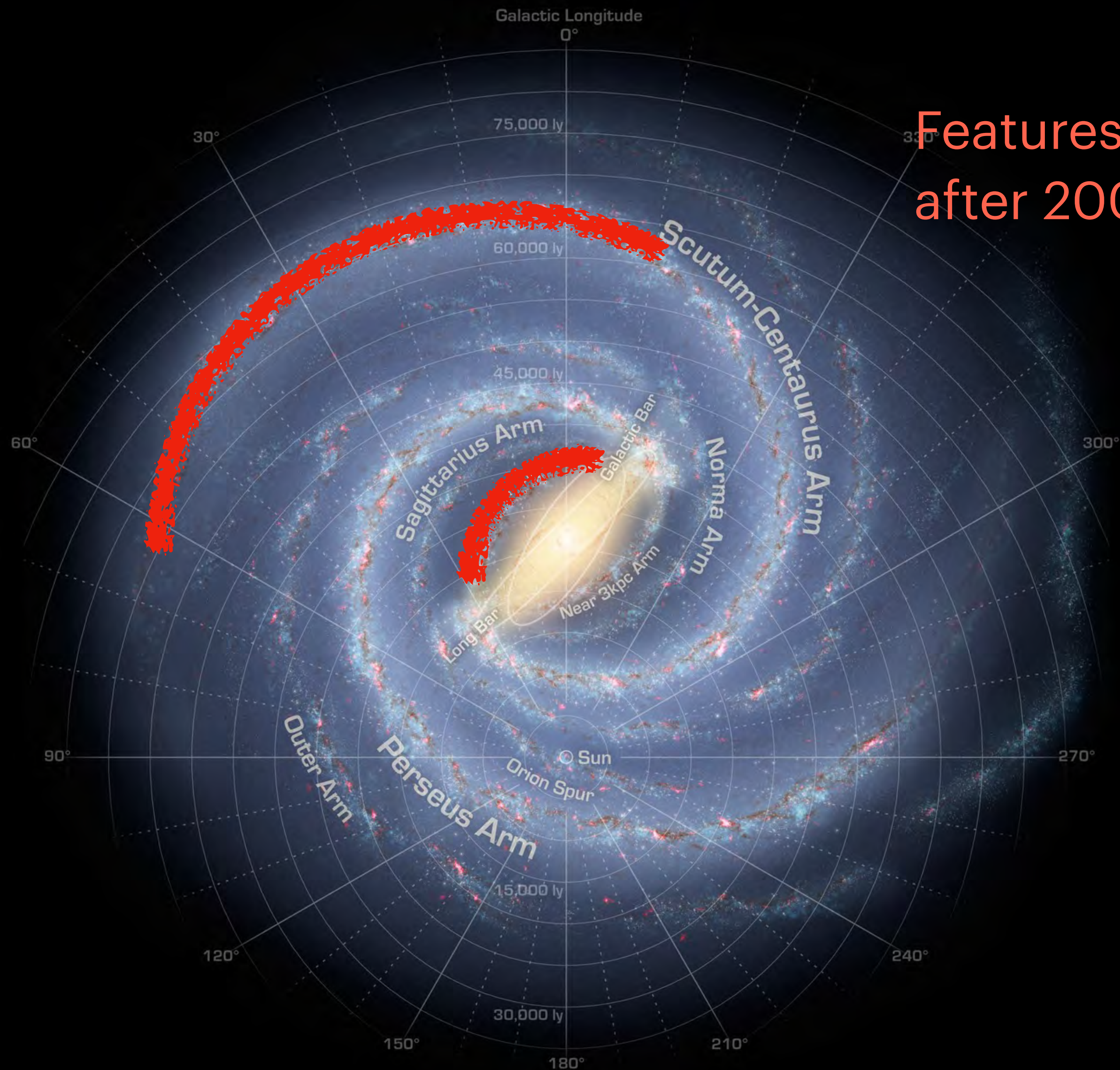




Spitzer Release/  
AAS Workshop  
2008

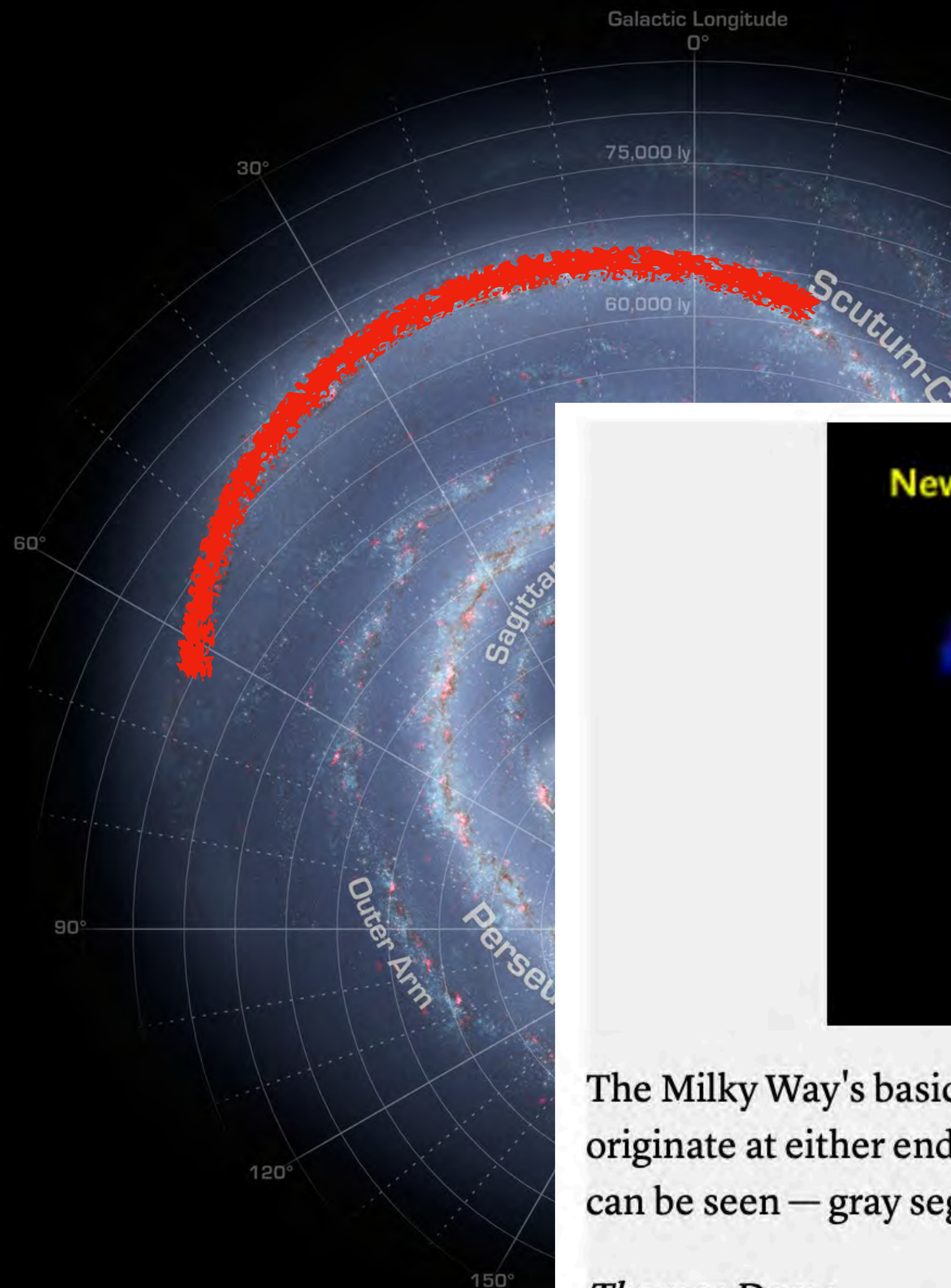


Spitzer Release/  
AAS Workshop  
2008

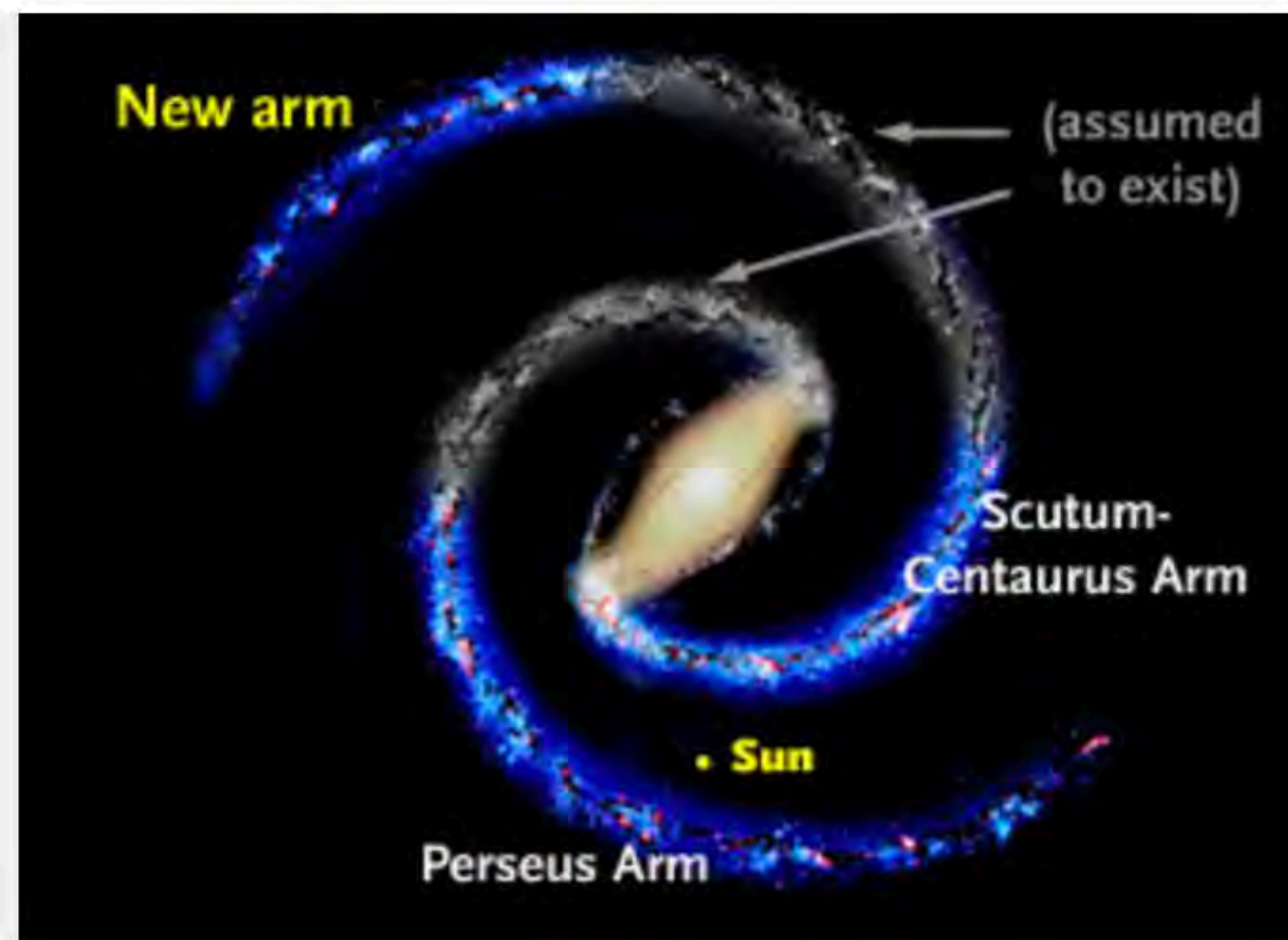


Features Discovered  
after 2008!

Spitzer Release/  
AAS Workshop  
2008

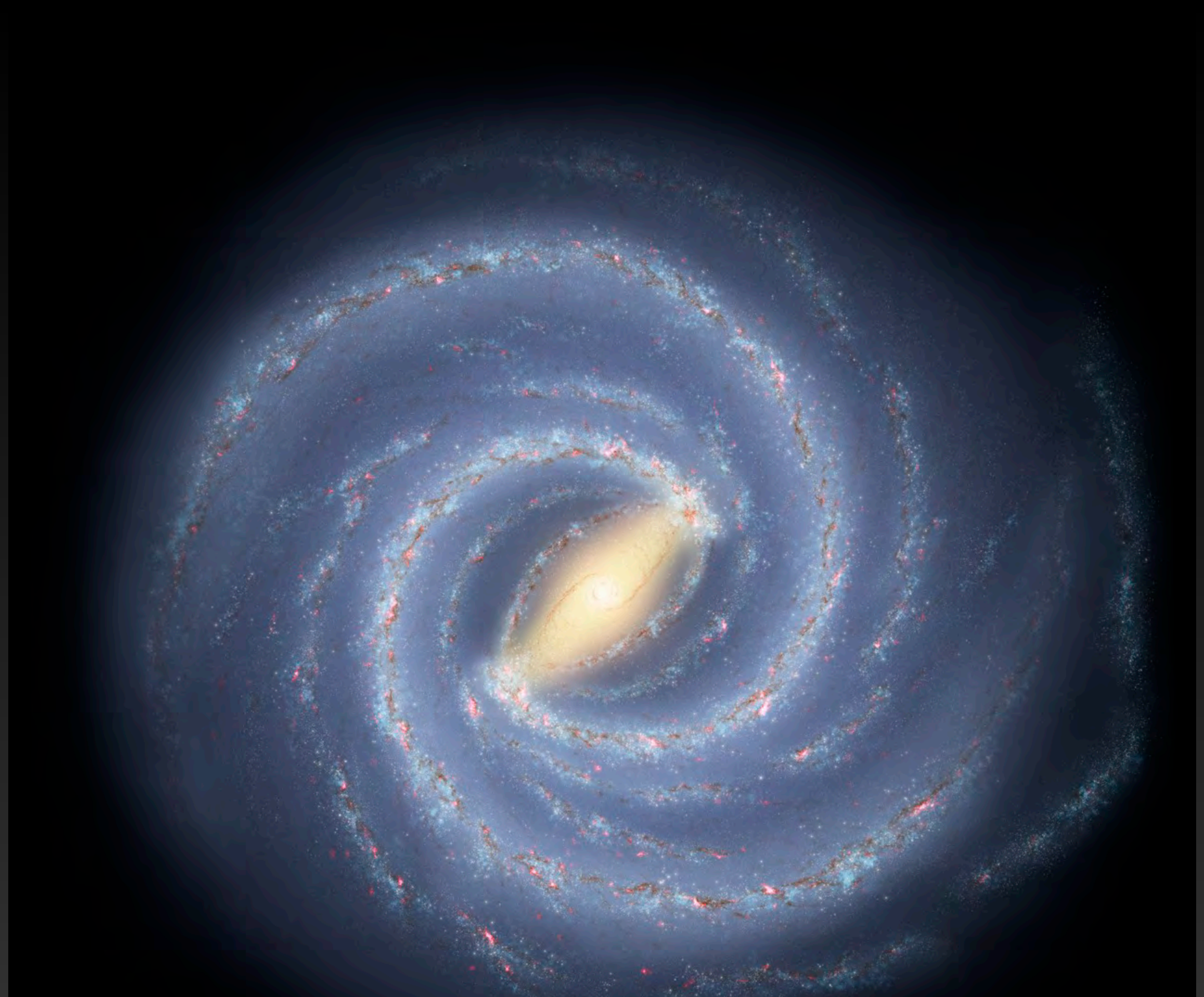


Features Discovered  
after 2008!



The Milky Way's basic structure involves two large spiral arms believed to originate at either end of an elongated central bar. But only parts of the arms can be seen — gray segments indicate portions not yet detected.

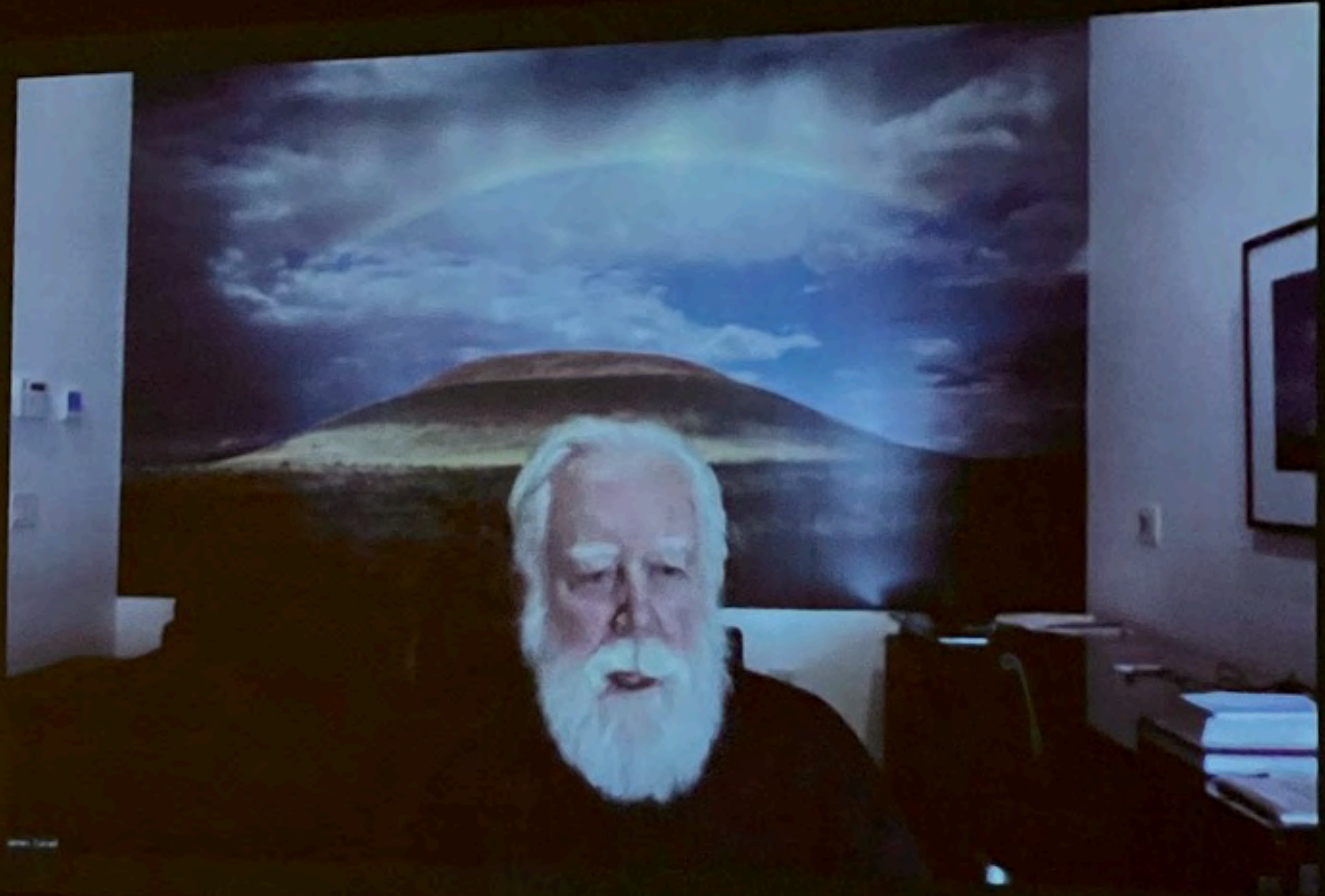
*Thomas Dame*



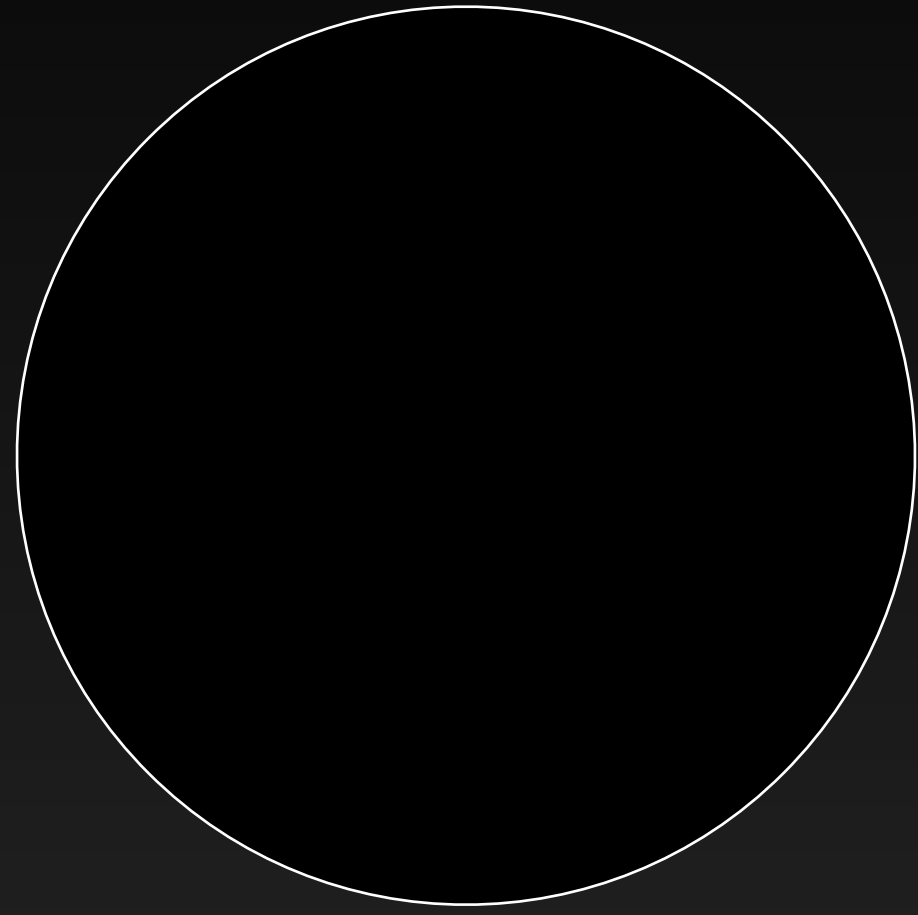
# Art as Hypothesis



NASA/JPL-Caltech/R. Hurt (SSC/Caltech)



James Lovelock



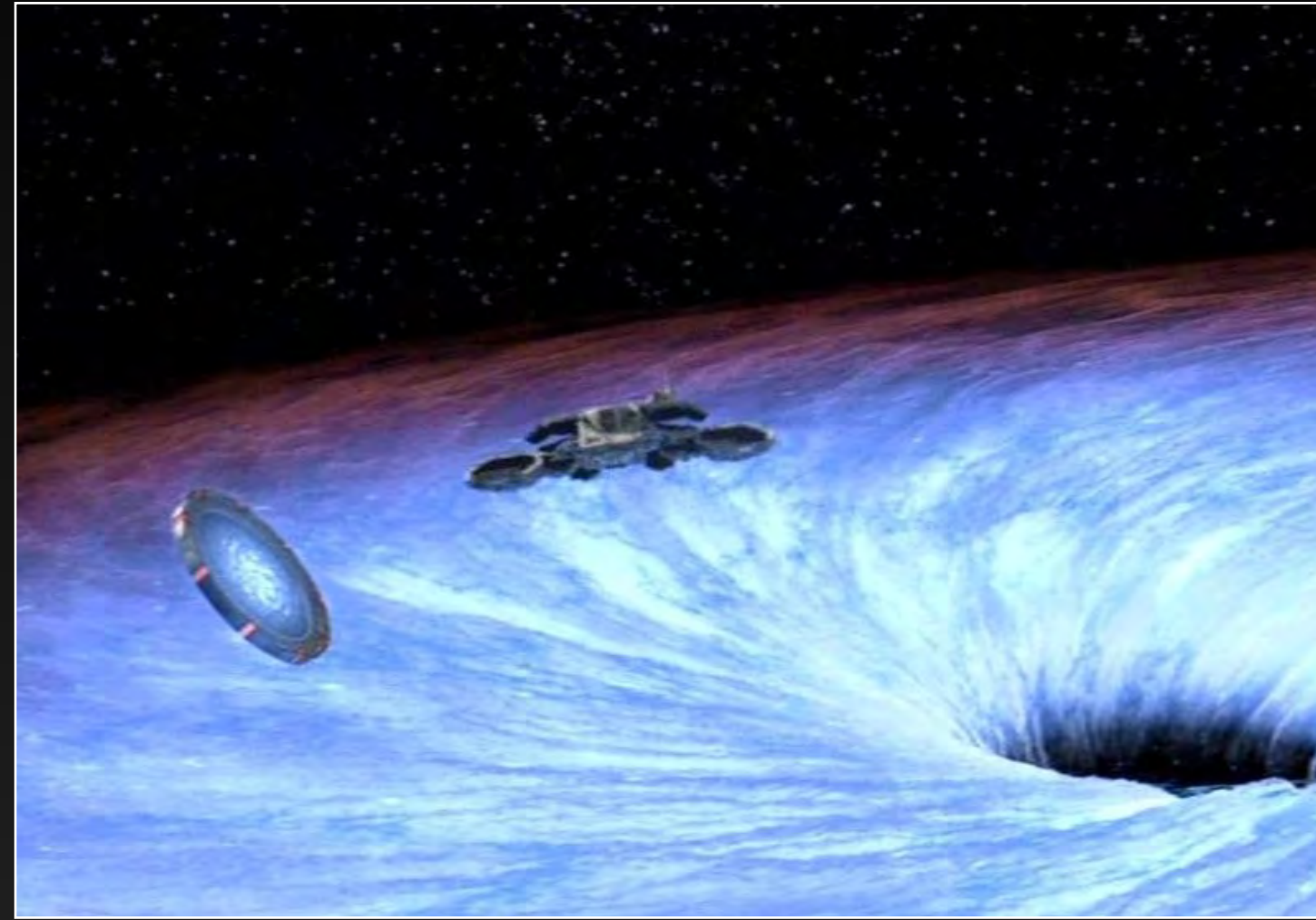
*Case Study*

**Black Holes**

# Pop Culture Black Holes through the Years...



Space: 1999 (1974)



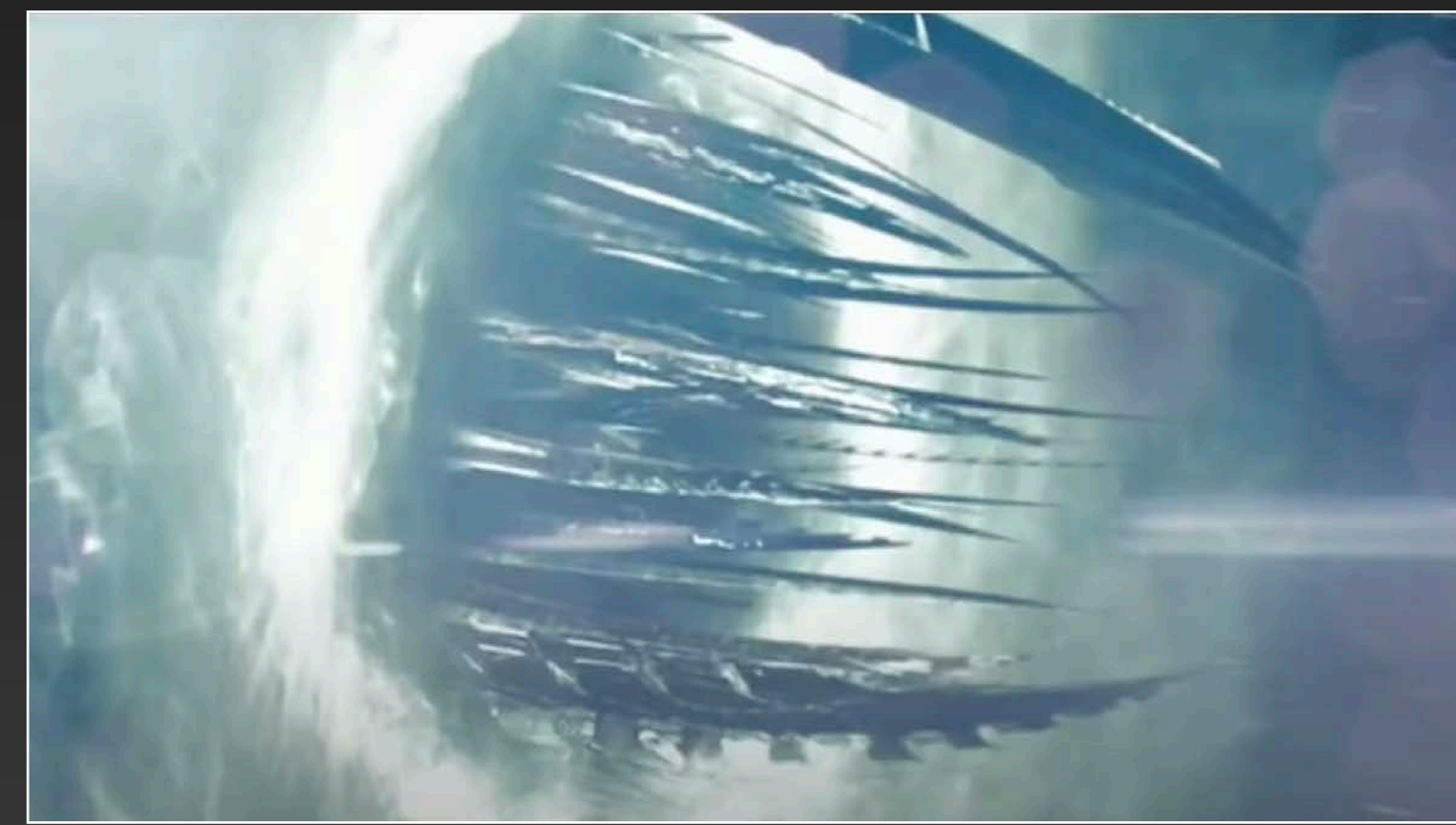
Stargate SG-1 (2006)



Cosmos 2 (2014)



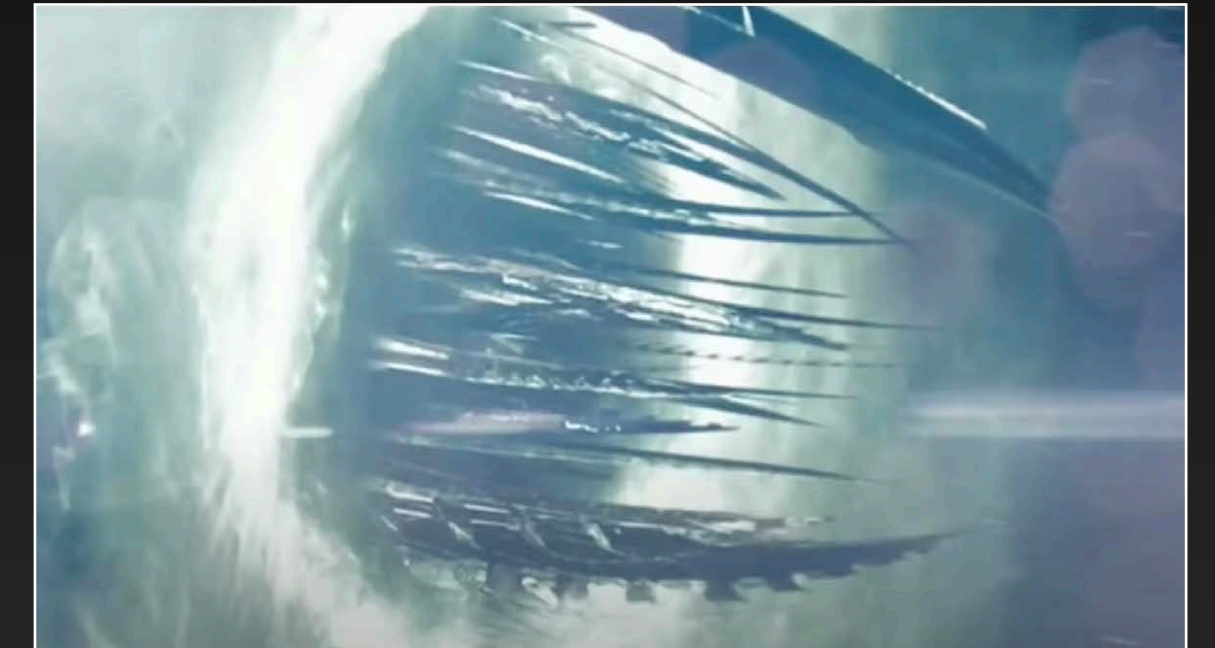
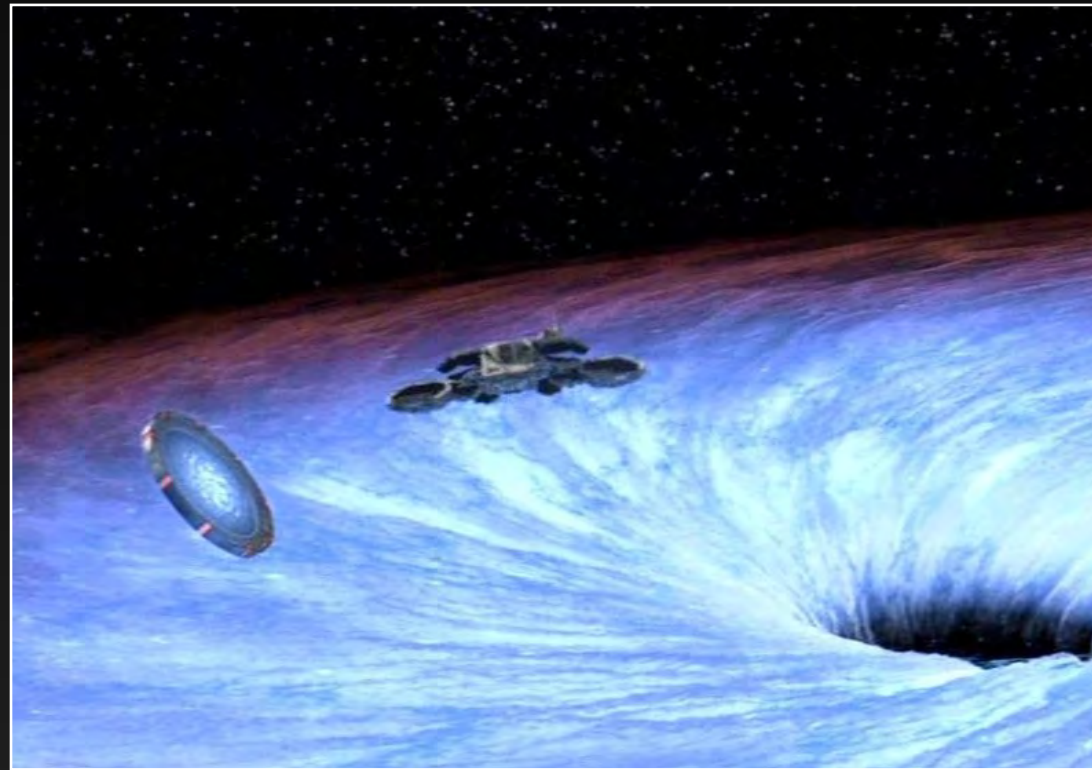
The Black Hole (1979)



Star Trek (2009)



# Typical Black Hole Categories

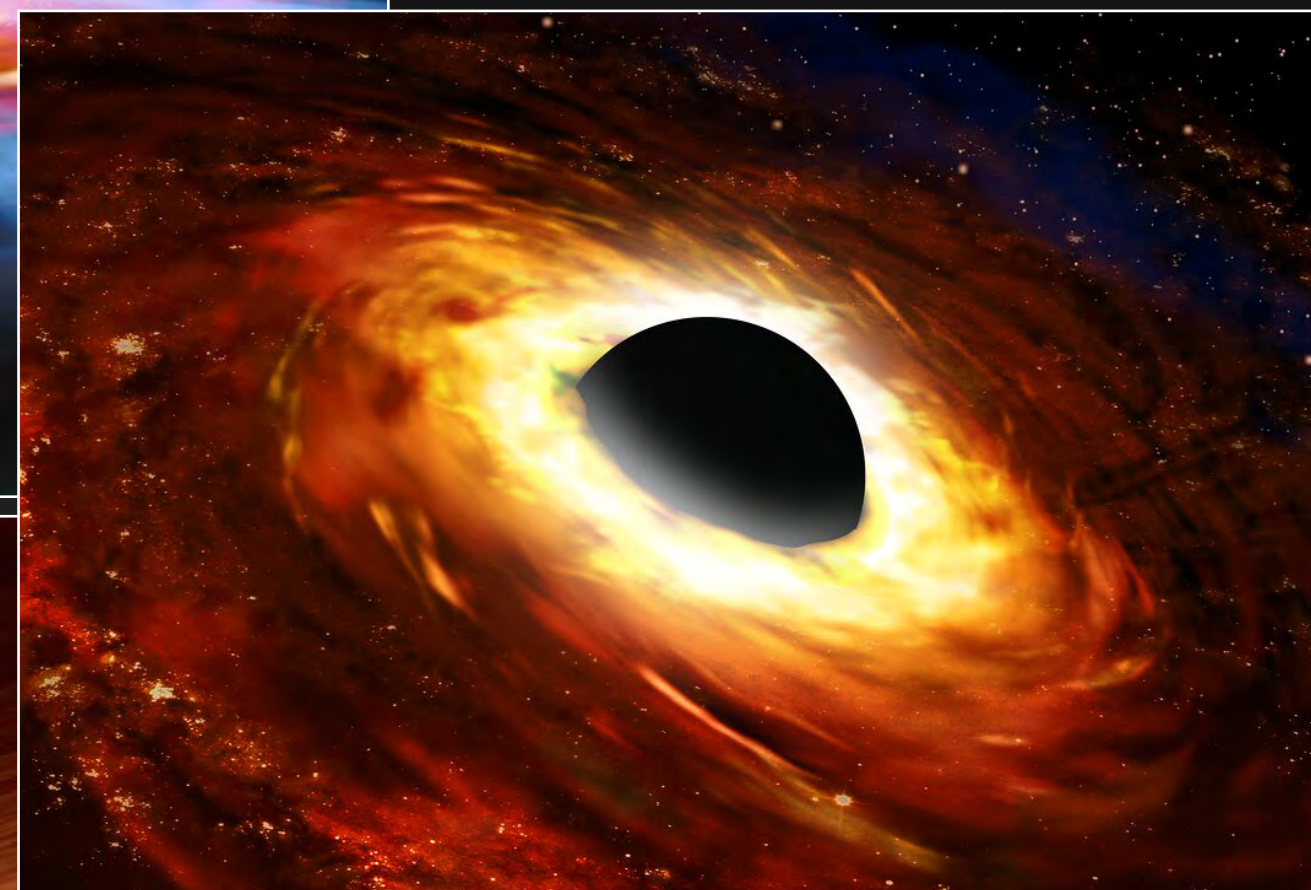


**Bowling Balls**

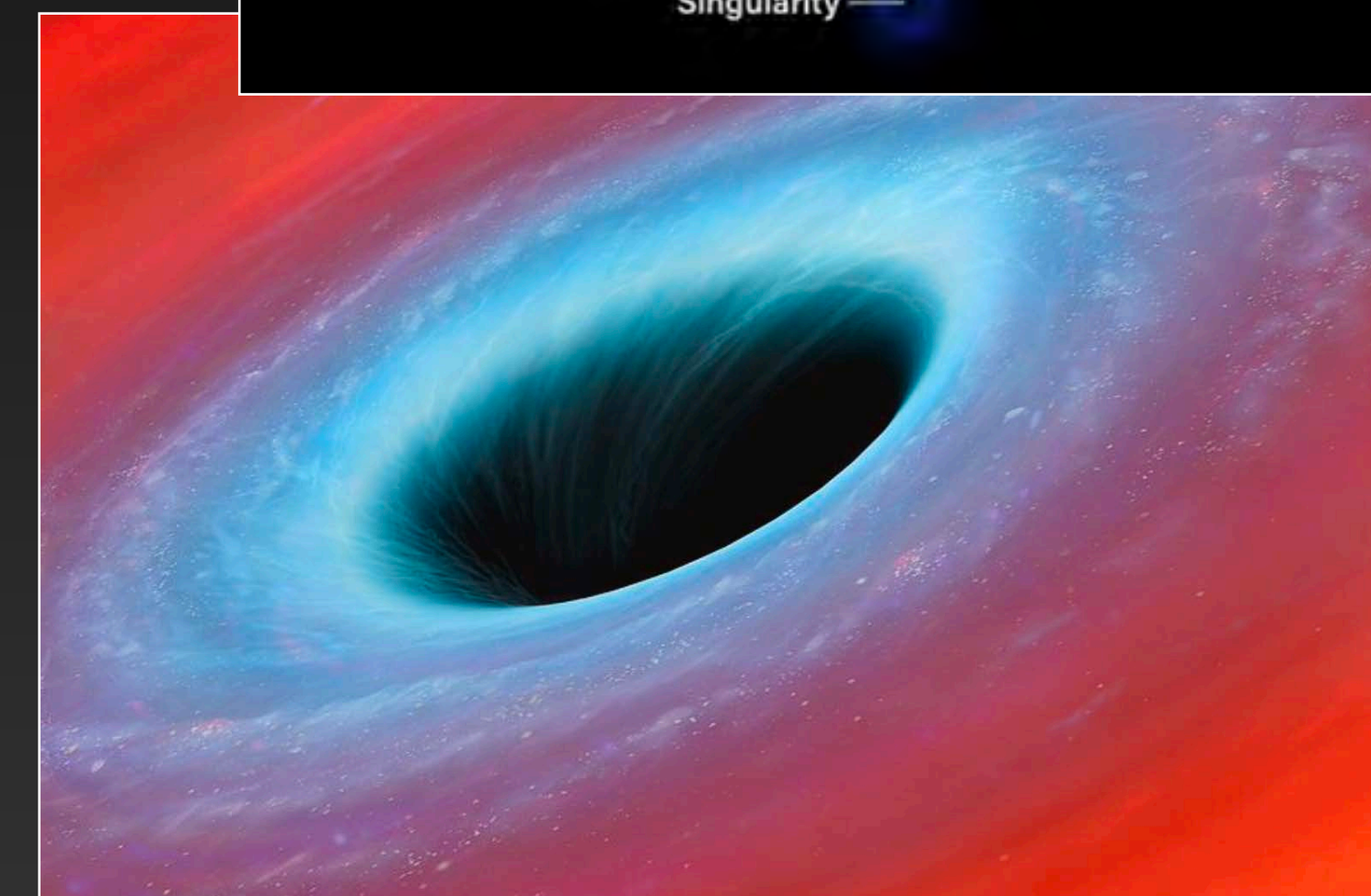
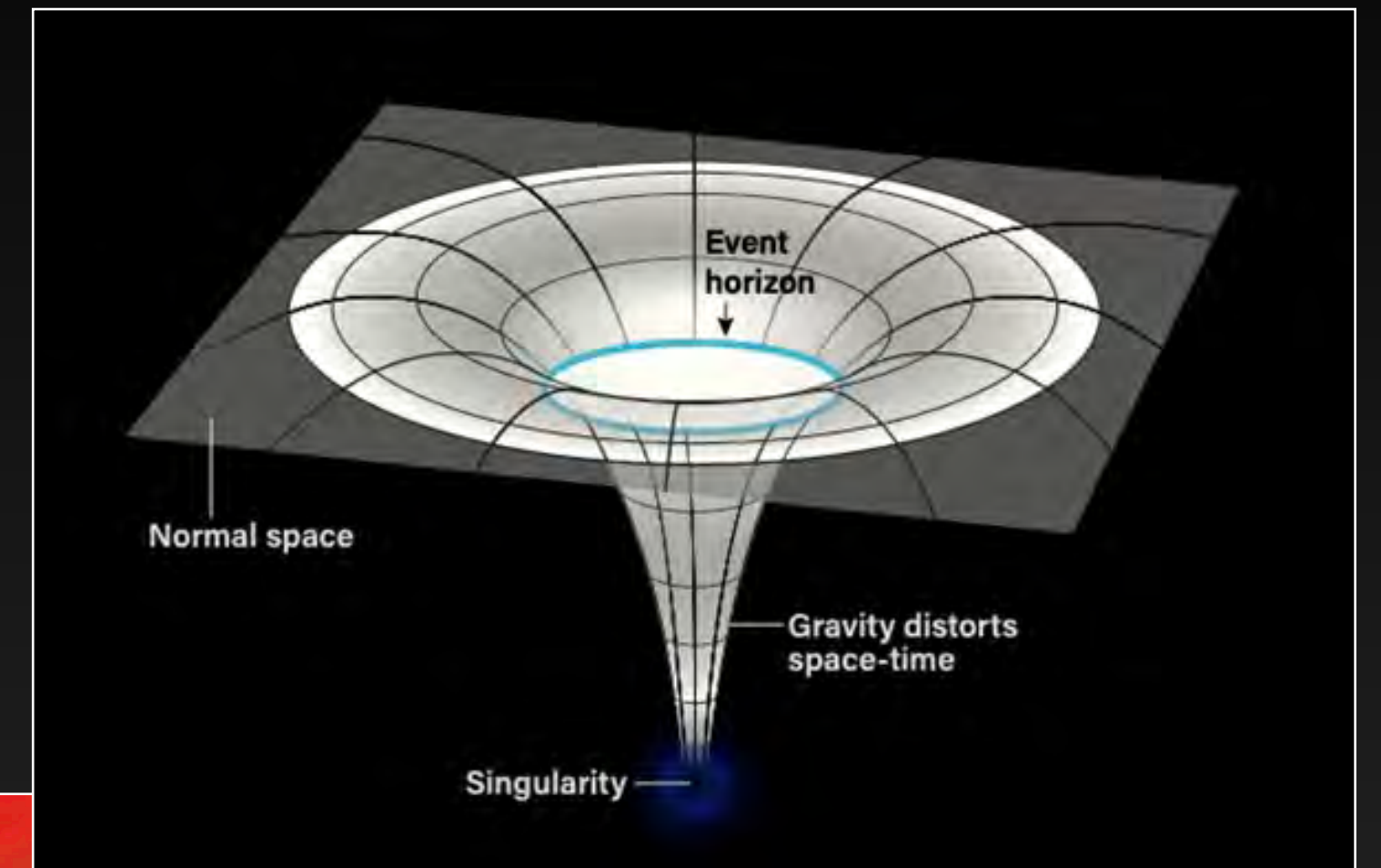
**Bathtub Drains**

*Flat Swirly Things  
with Lens Flares*

# Classic Astro Viz? Kind of the Same...



**Bowling Balls**



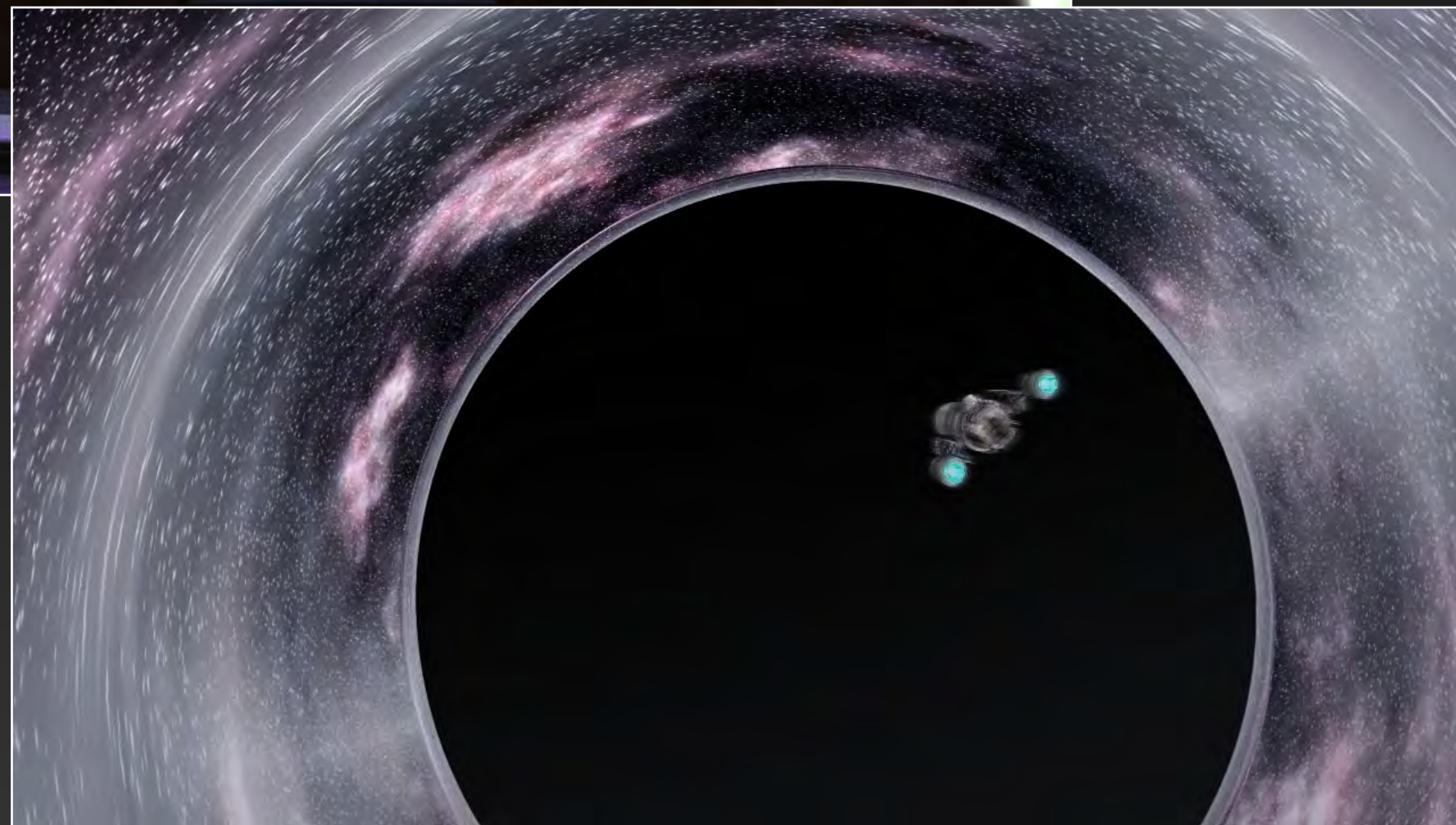
**Bathtub Drains**

**But we've known for over 100 years that  
black holes WARP LIGHT!**

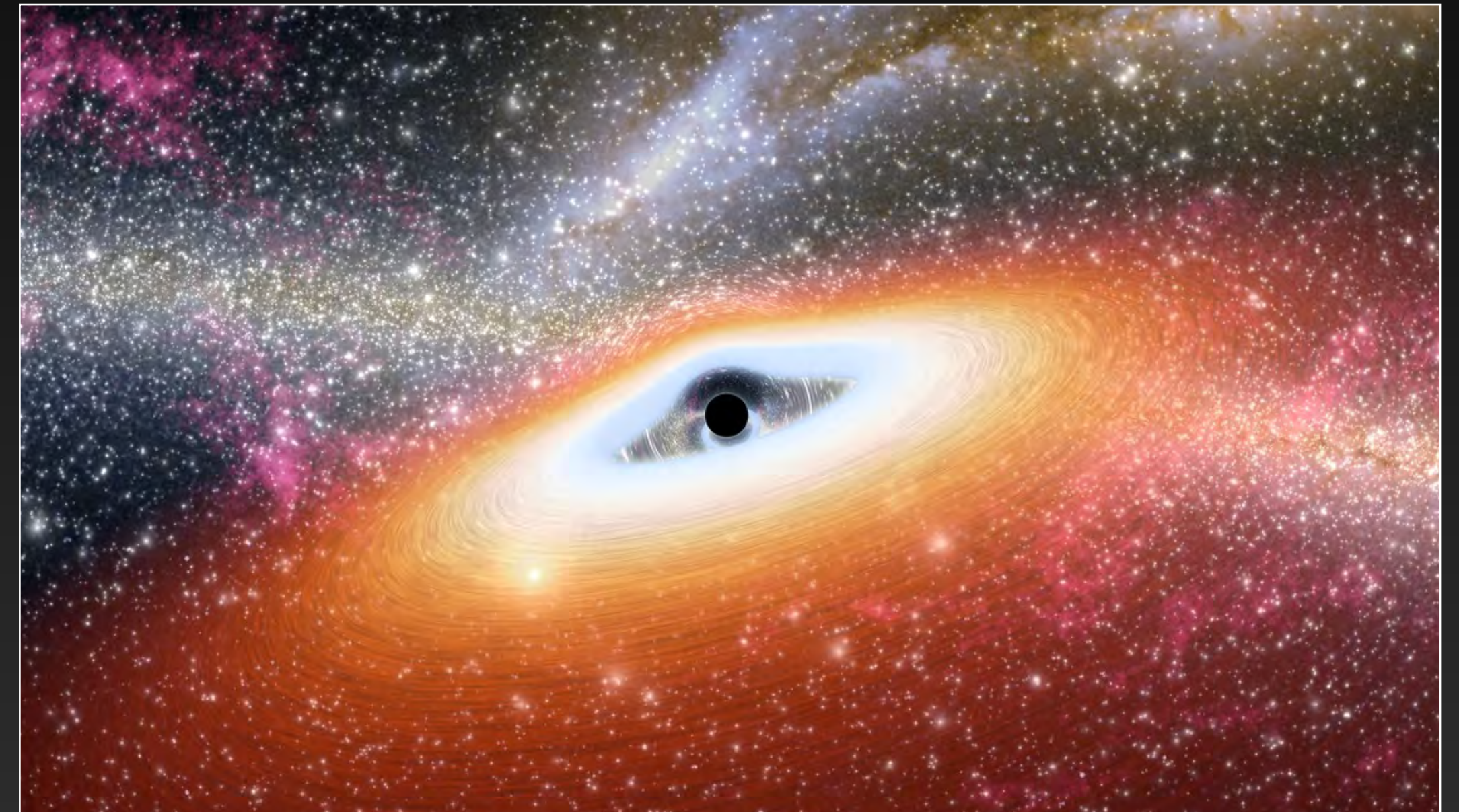
# Why So Rare in Viz?

- Gravitational lensing is harder to create
- It is not what people expected to see

# Getting the Warps into Black Holes



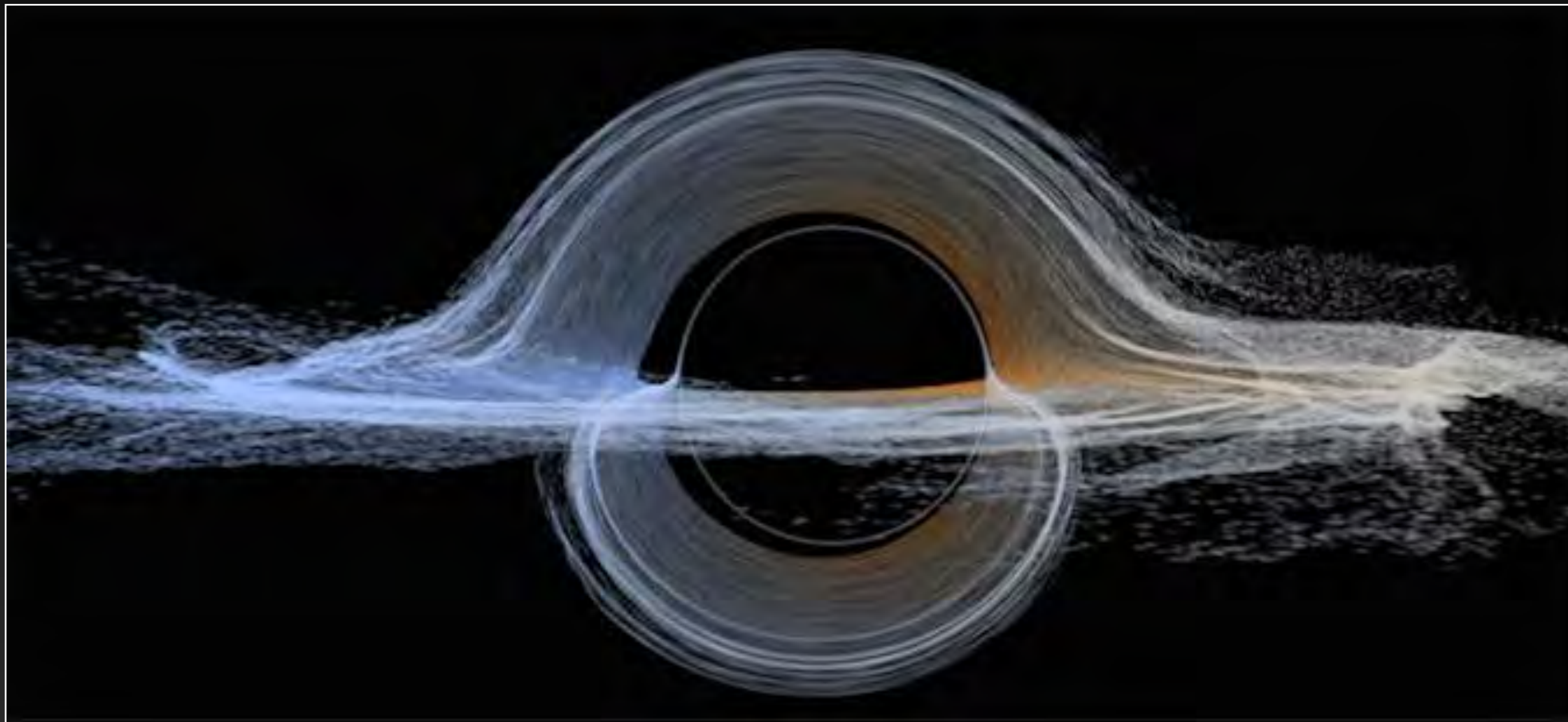
2008 "Spaceship Spitzer"



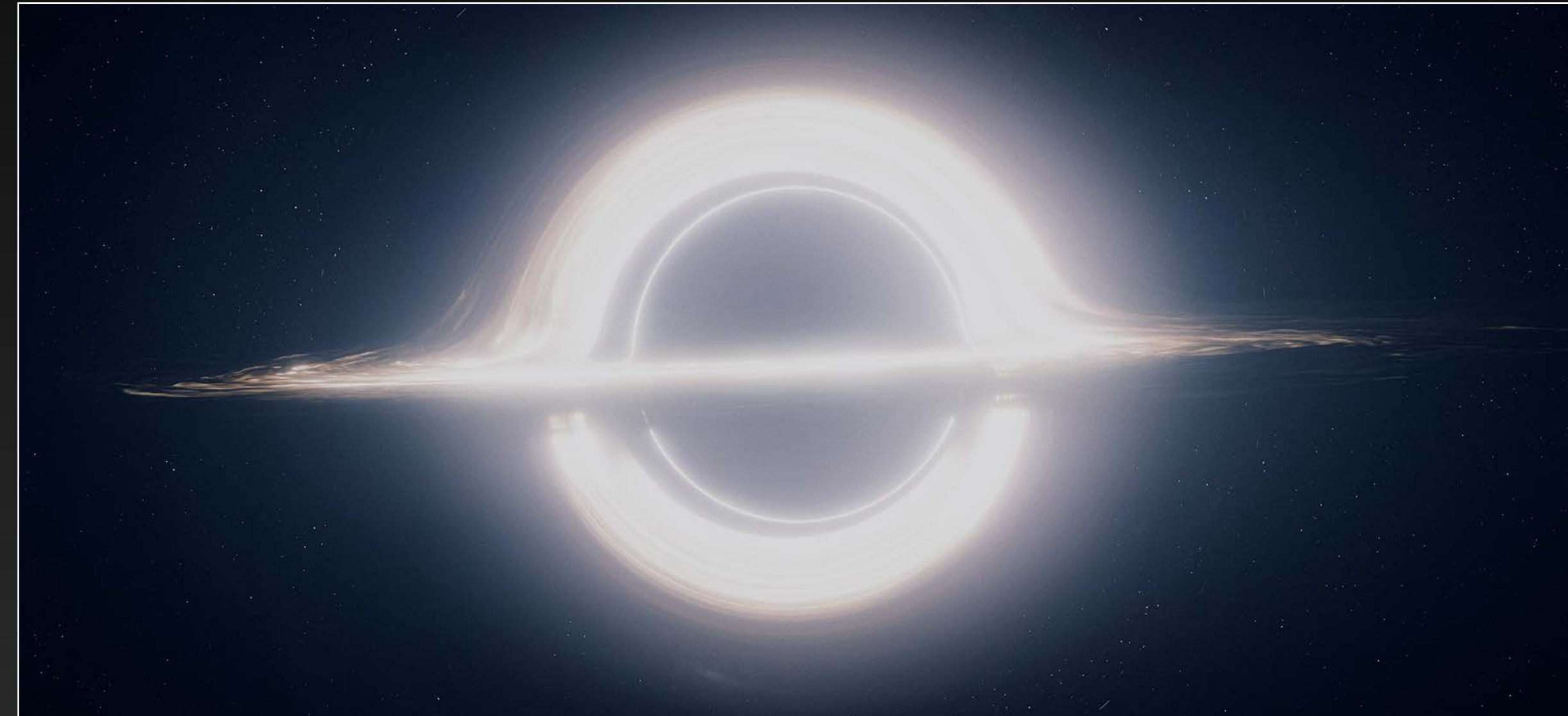
2010 Spitzer Release

# 2014: Then Came “Interstellar”...

Director: Chris Nolan Scientist: Kip Thorne



Intermediate “research” version  
including doppler effects



Final “movie” version

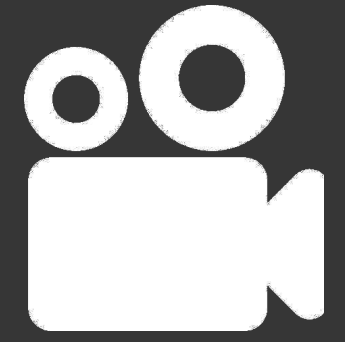
# ...And Now Even Star Trek Gets It Right!



Star Trek Lower Decks  
(2020)



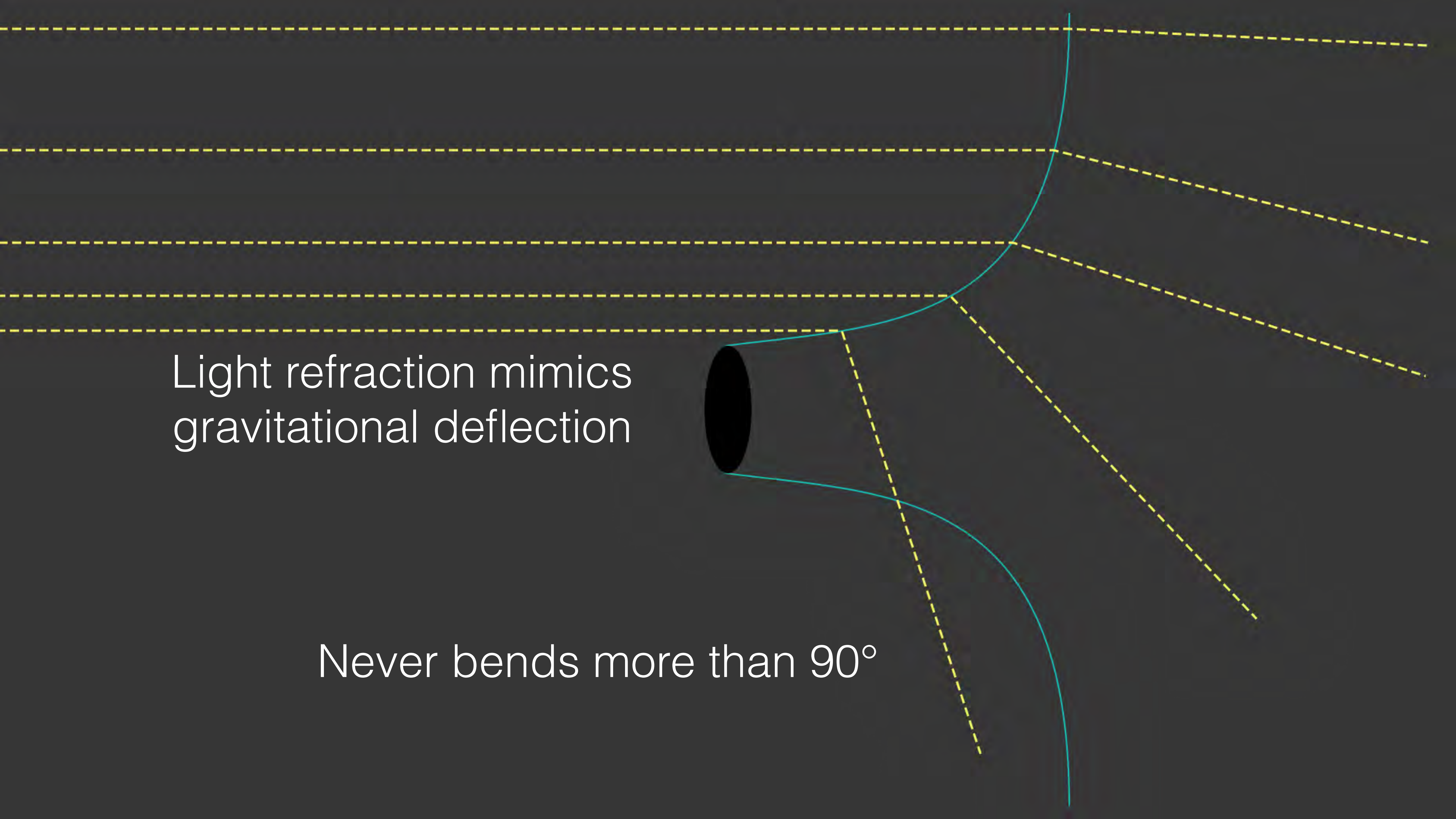
Star Trek: Strange New Worlds  
(2022)



Refractive  
“funnel lens”

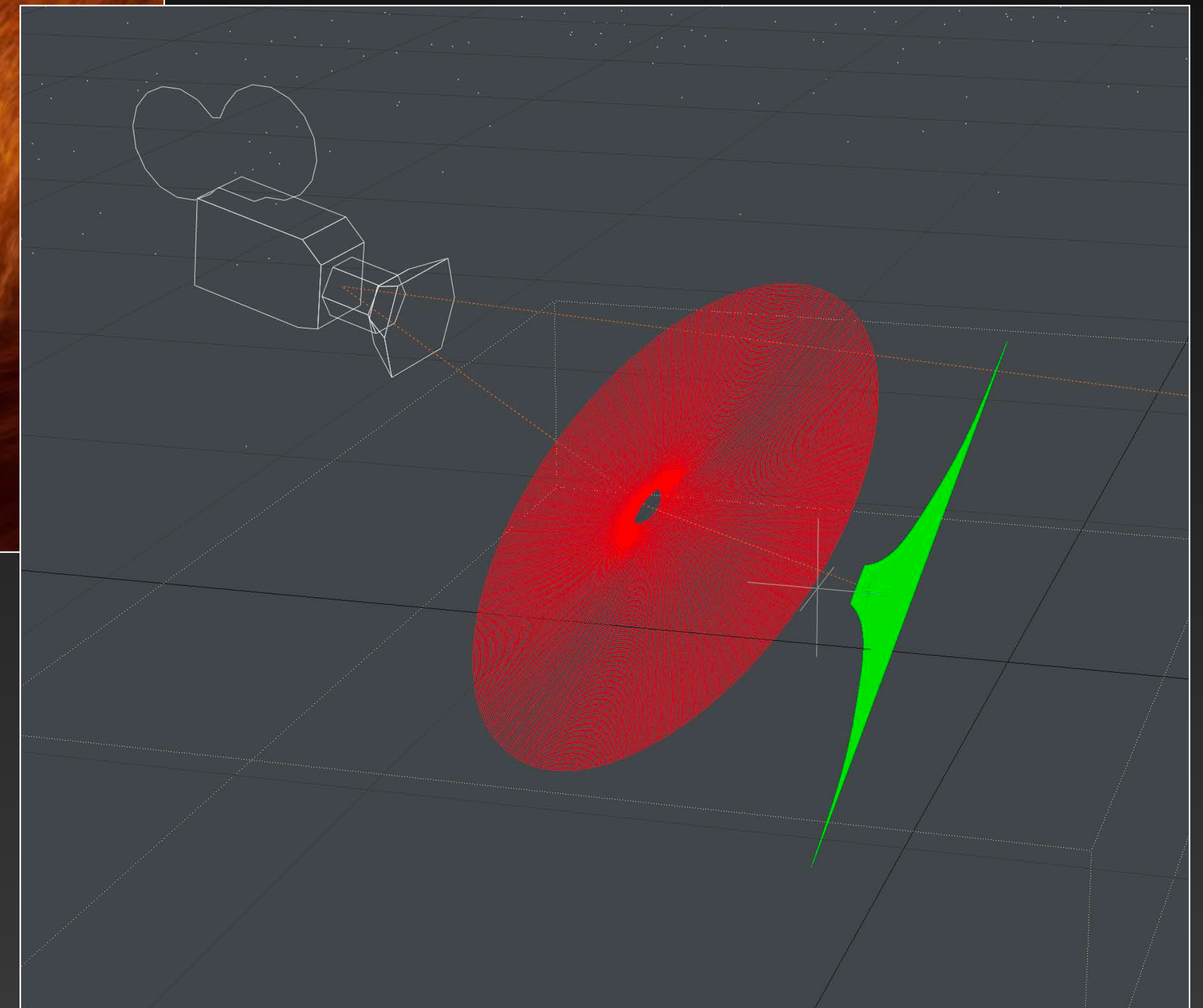
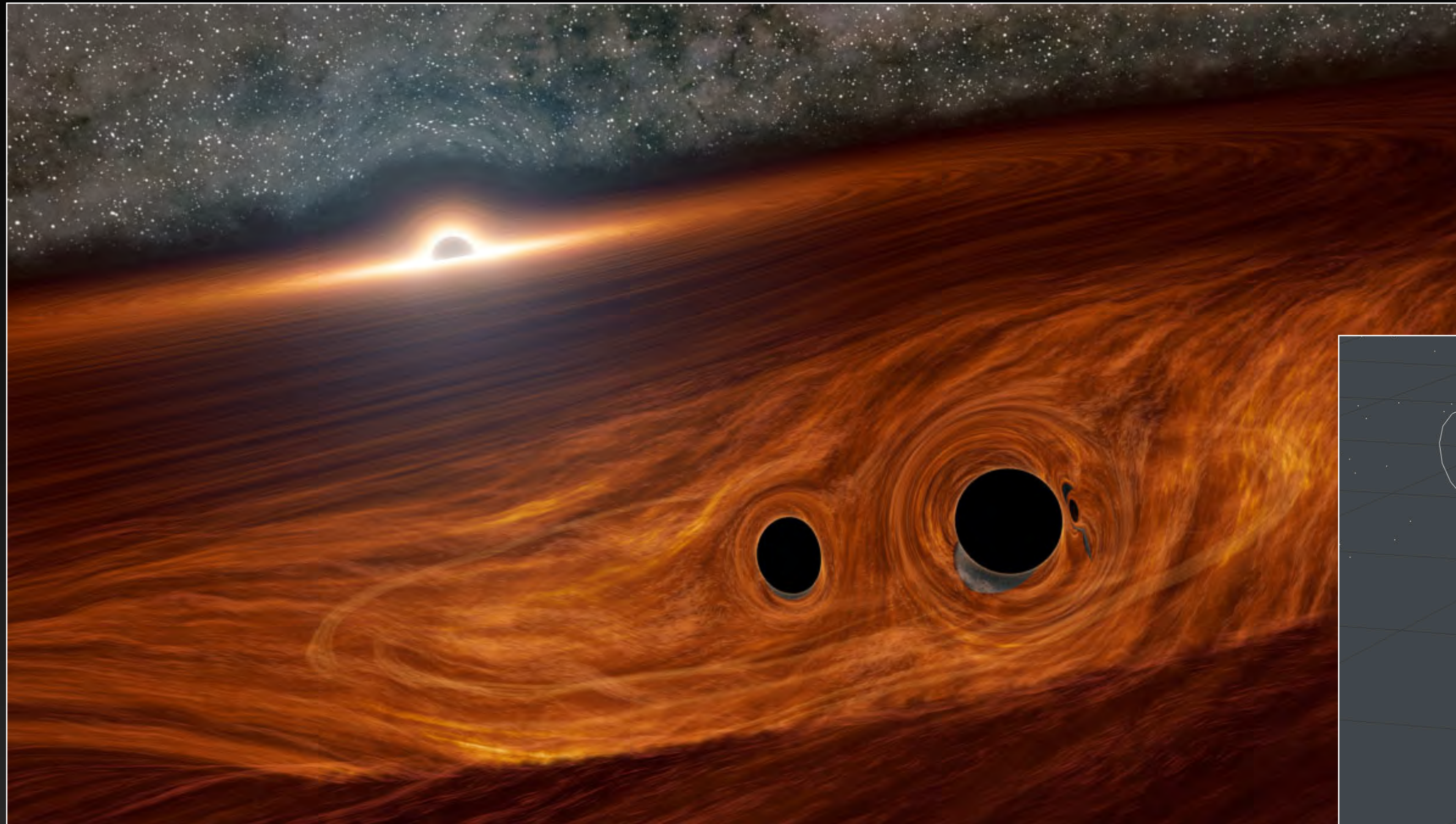




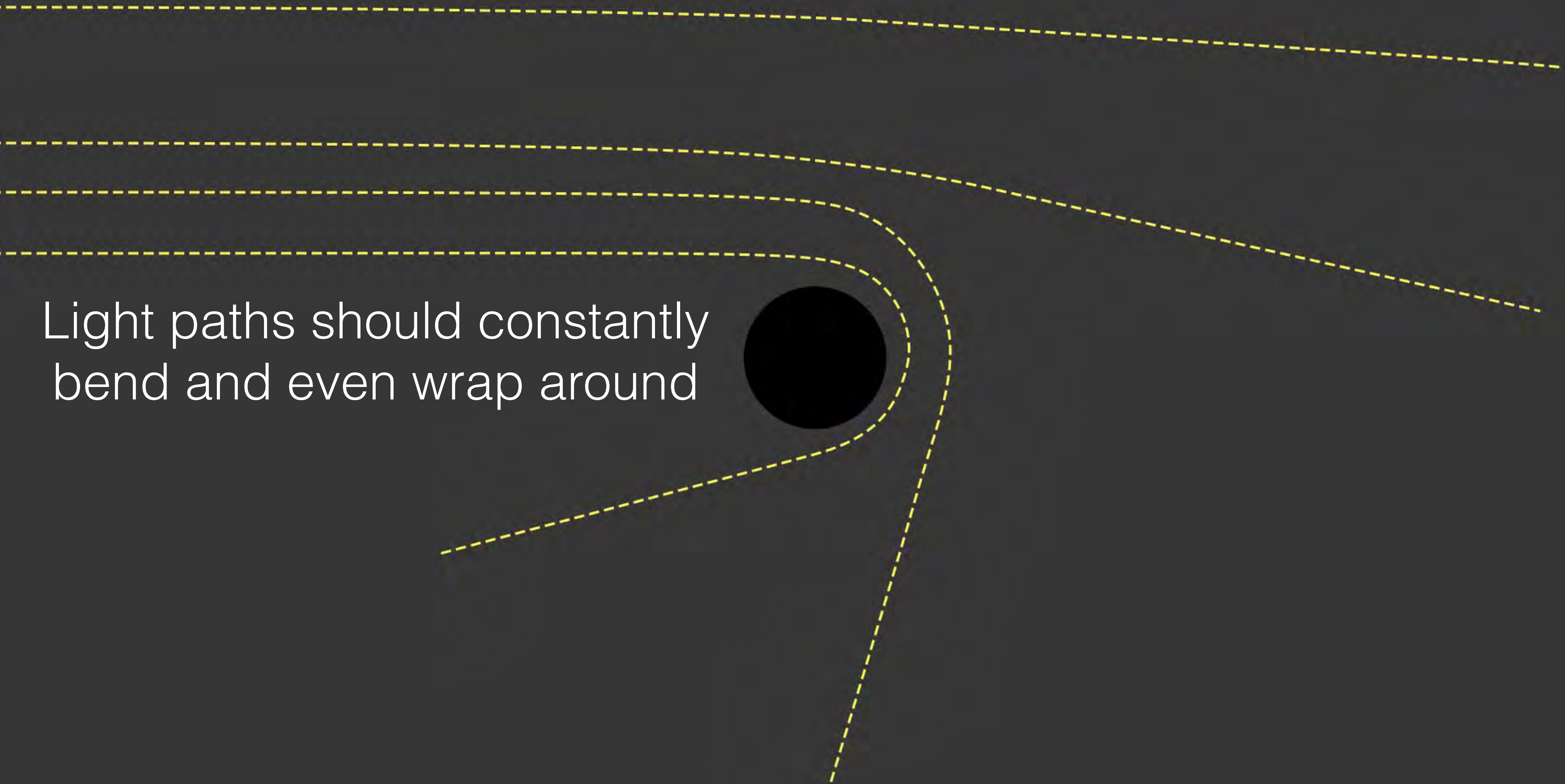
A diagram illustrating the concept that light refraction mimics gravitational deflection. A black oval on the left represents a lens. Five horizontal dashed yellow lines represent light rays traveling from left to right. As they pass the lens, they are deflected downwards. The deflection is most pronounced for the rays closest to the lens, with the bottom-most ray bending at a 90-degree angle. The text "Light refraction mimics gravitational deflection" is positioned to the left of the lens, and "Never bends more than 90°" is positioned below the lens.

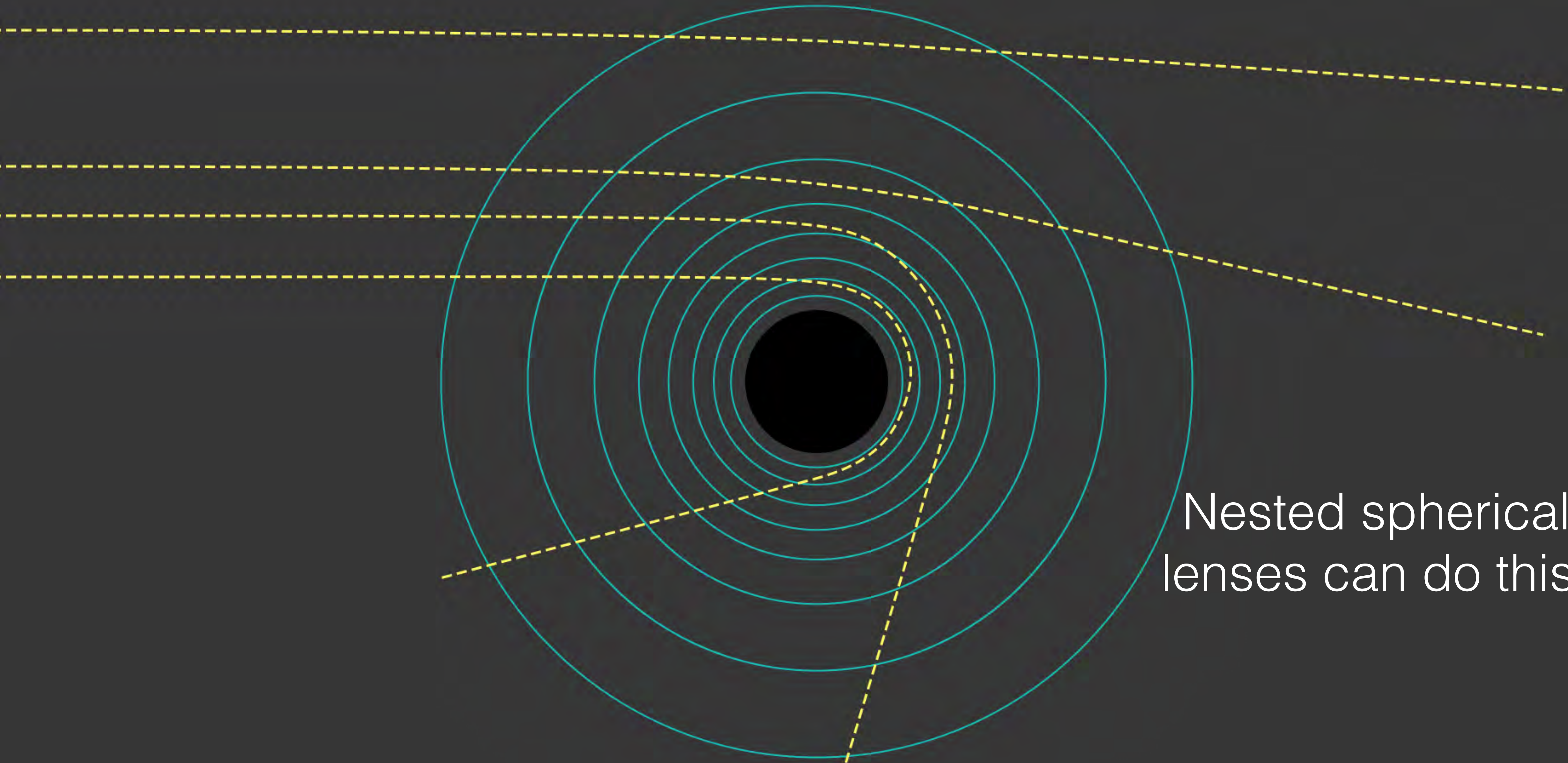
Light refraction mimics  
gravitational deflection

Never bends more than  $90^\circ$



Light paths should constantly bend and even wrap around



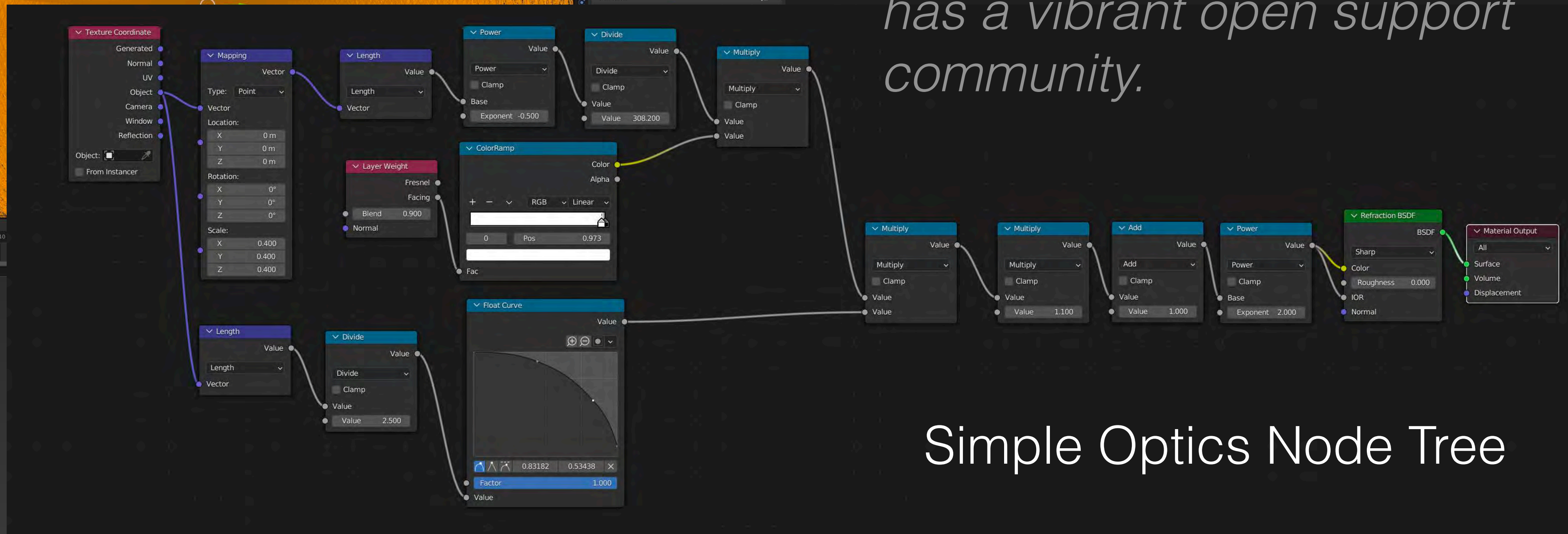
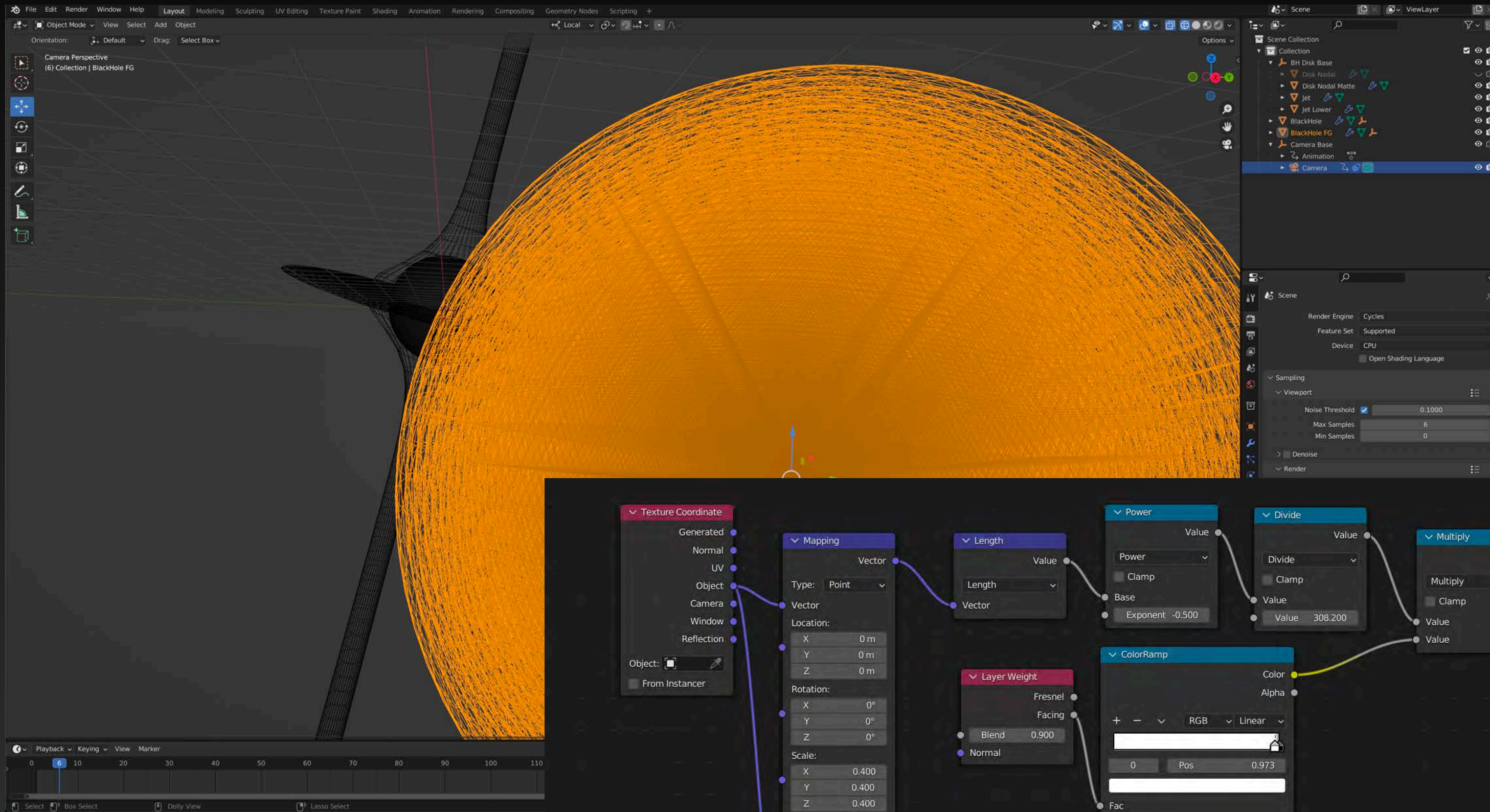


Nested spherical lenses can do this!

# “Open Source” Black Holes in Blender

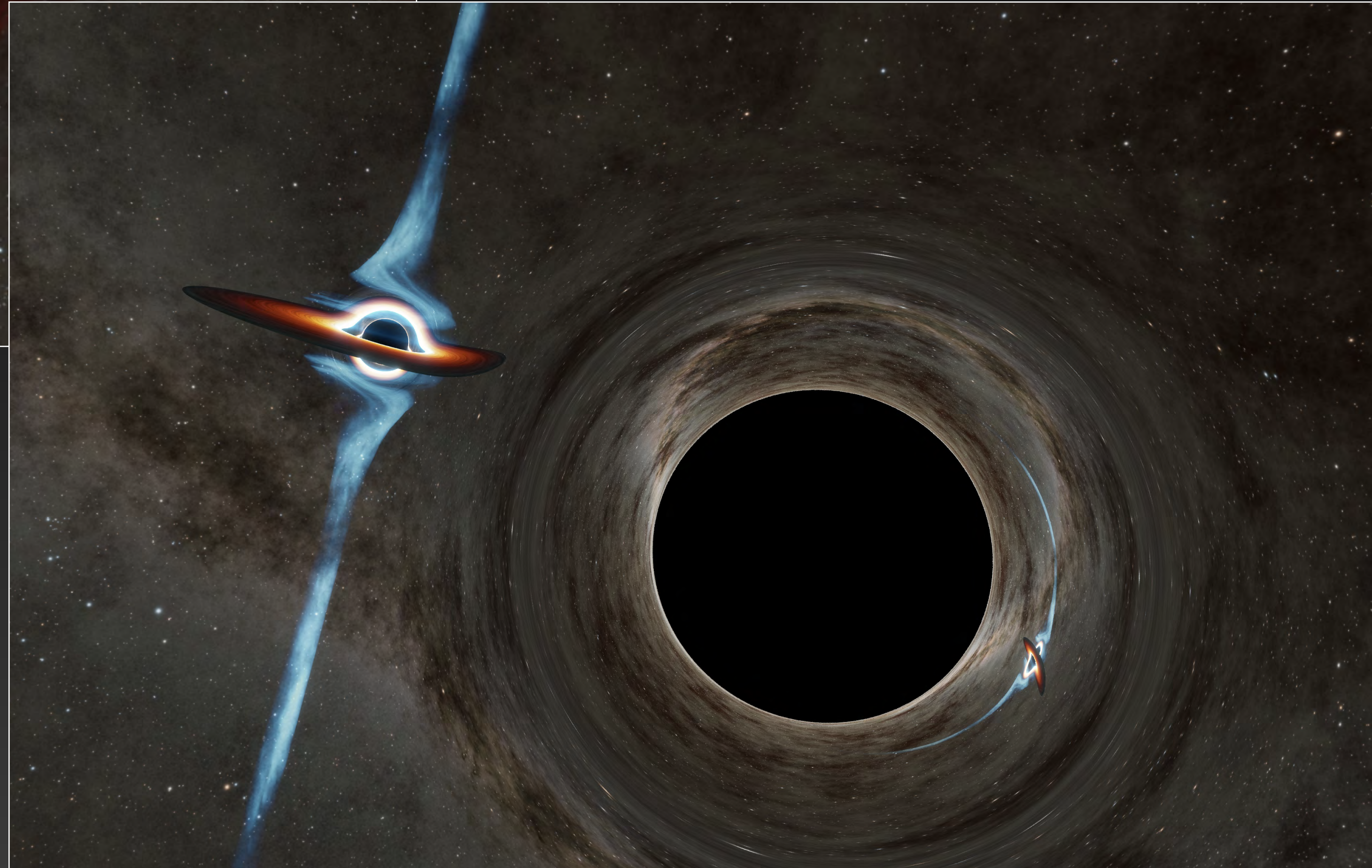
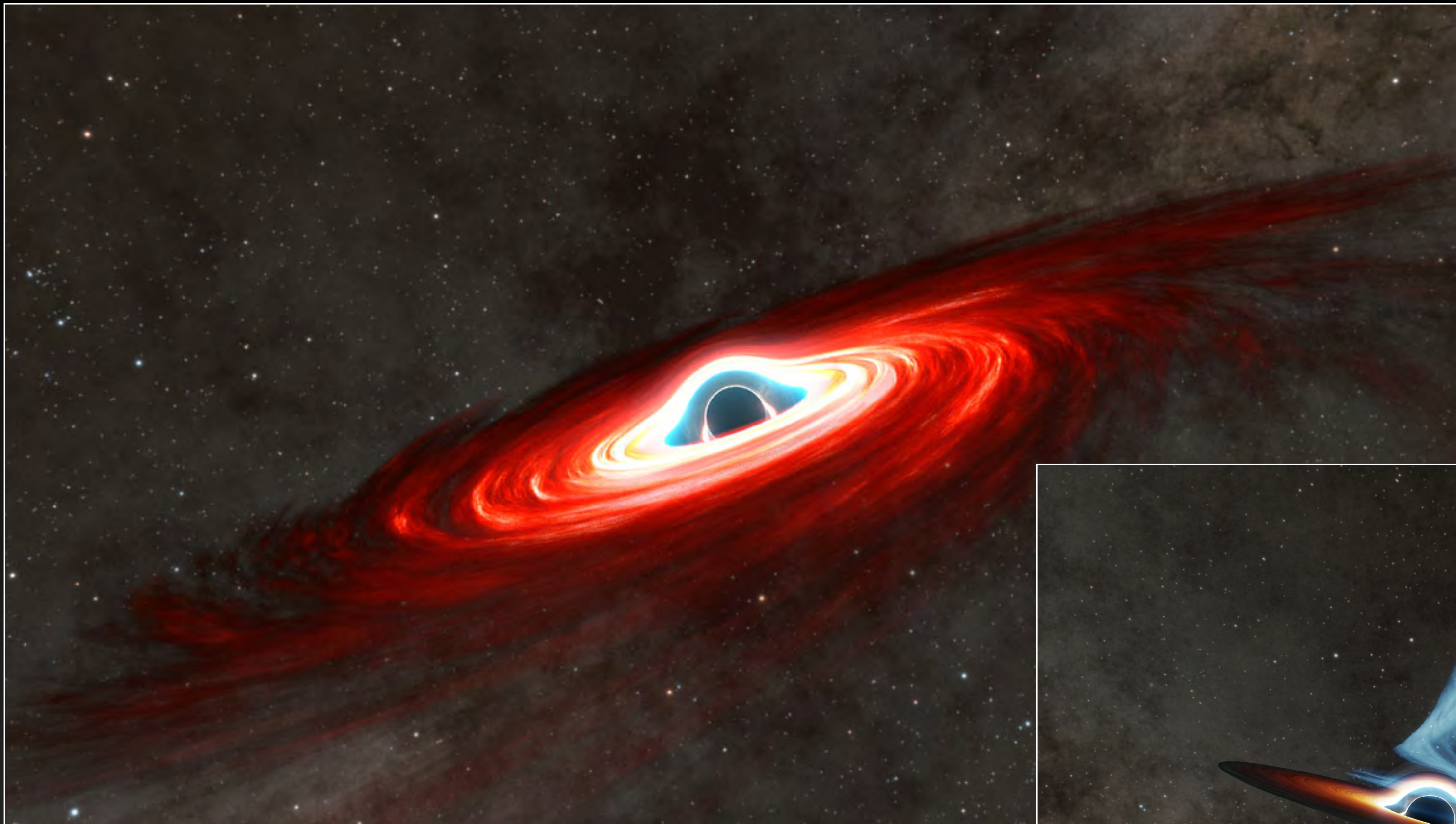
*Blender is a free, open source solution for 3D models & animations.*


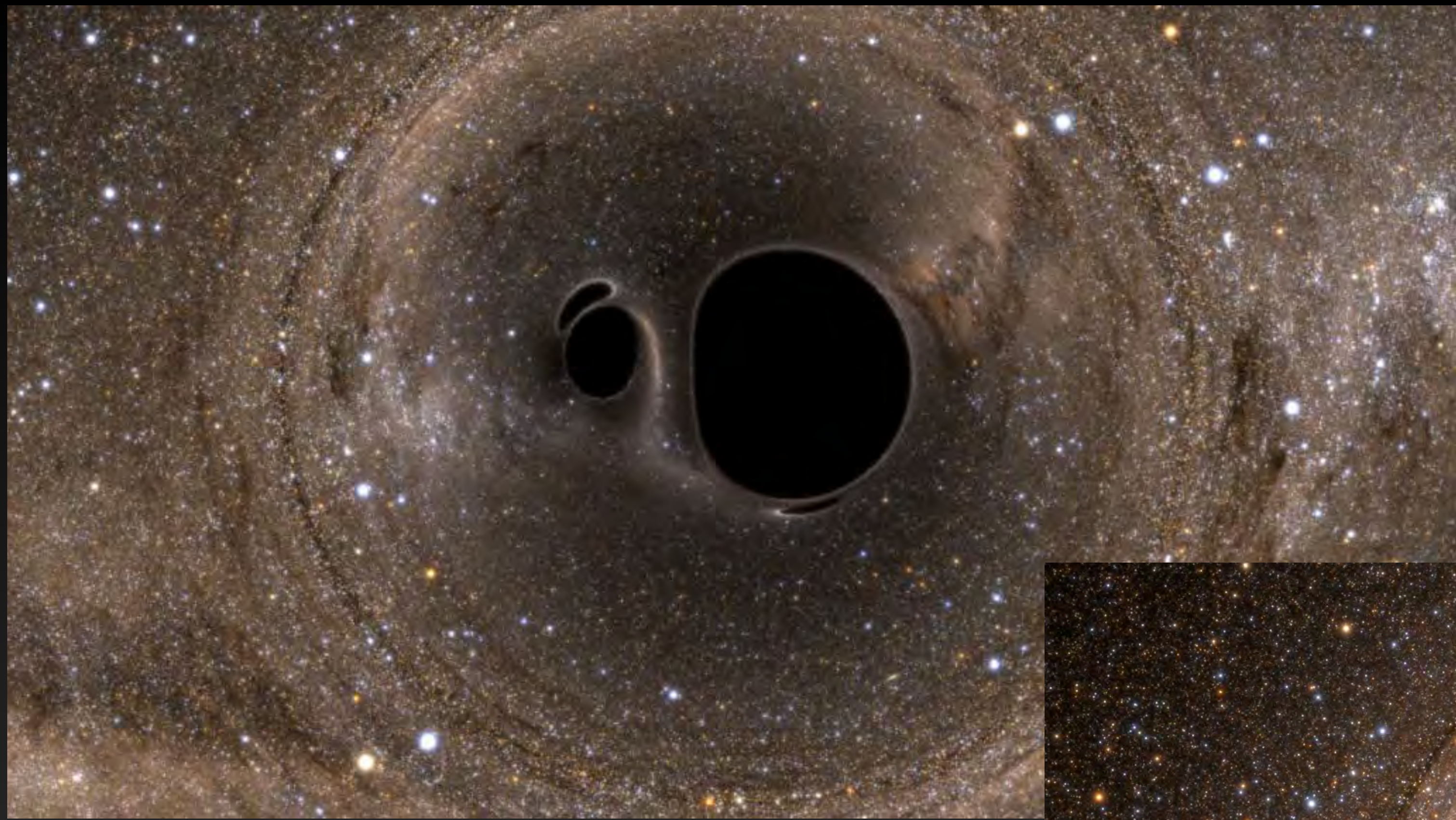
*Its features rival top commercial packages, and it has a vibrant open support community.*





Short Blender black hole renders are now (qualitatively) in the same ballpark...

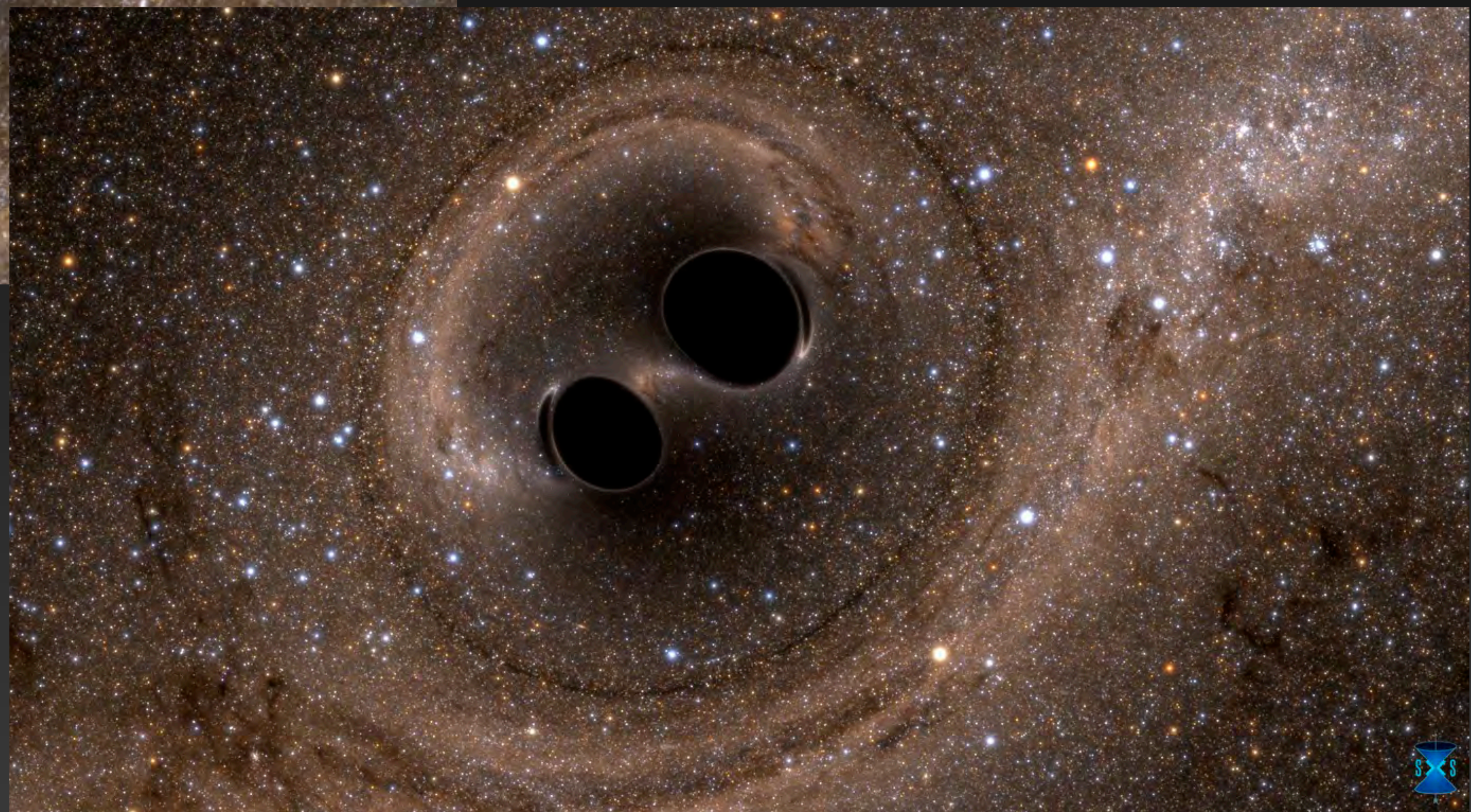




**SIMULATING EXTREME SPACETIMES**  
*Black holes, neutron stars, and beyond...*

<https://www.black-holes.org>

...as full general relativistic ray traced black hole simulations using supercomputer clusters!







**Never. Again.**

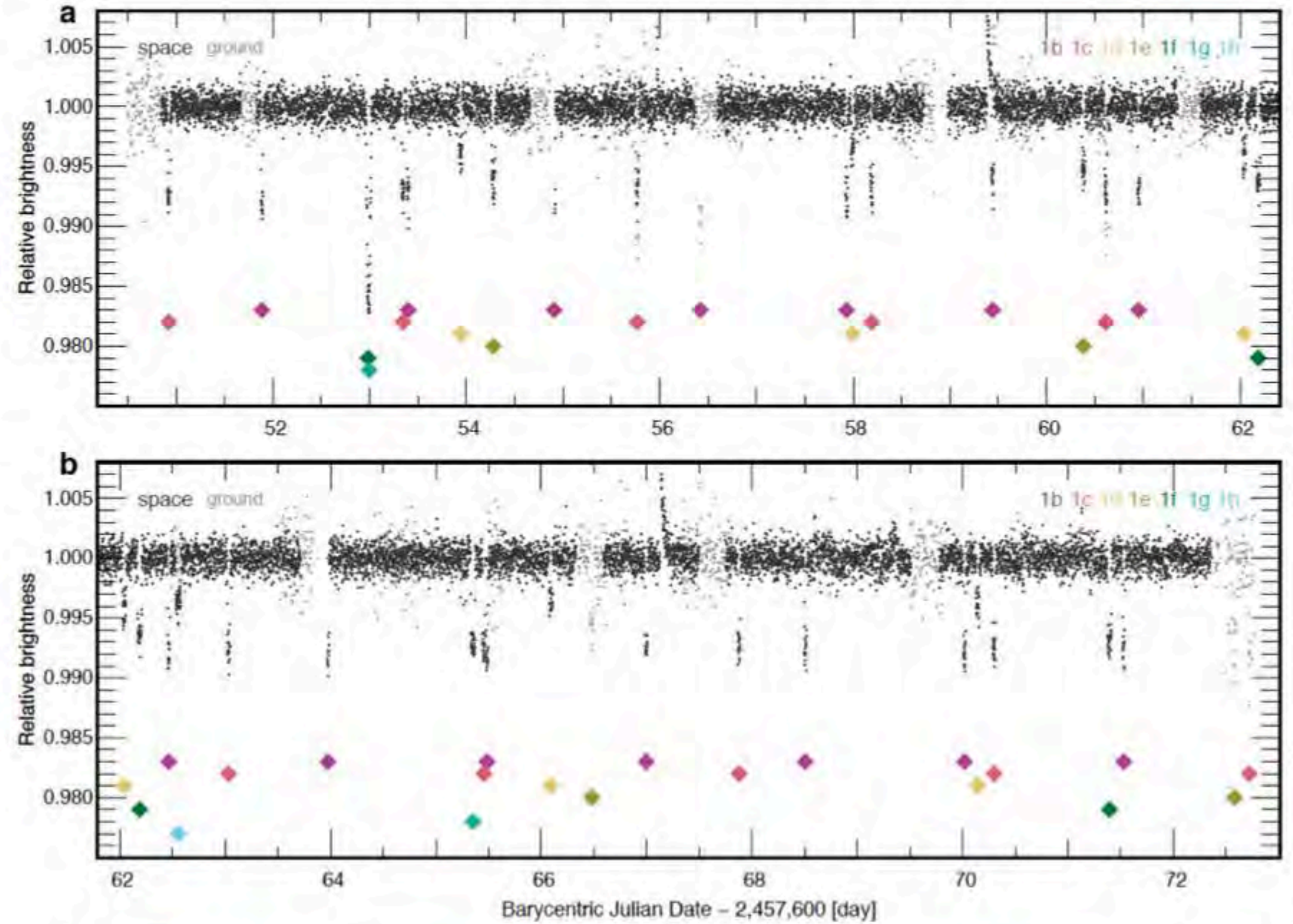


*Case Study*

**Exoplanets**



# TRAPPIST-1 Light Curve



"All the News  
That's Fit to Print"

# The New York Times

Late Edition

Today, patchy morning fog, partly sunny, warm, high 64. Tonight, mostly cloudy, mild, low 52. Tomorrow, clouds and sunshine, showers, high 66. Weather map is on Page B9.

VOL. CLXVI ... No. 57,517

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NEW YORK, THURSDAY, FEBRUARY 23, 2017

\$2.50



A rendering of newly discovered Earth-size planets orbiting a dwarf star named Trappist-1 about 40 light-years from Earth. Some of them could have surface water.

## Circling a Star Not Far Away, 7 Shots at Life

By KENNETH CHANG

Not just one, but seven Earth-size planets that could potentially harbor life have been identified orbiting a tiny star not too far away, offering the first realistic

## Uber's Culture Of Gutsiness Under Review

By MIKE ISAAC

SAN FRANCISCO — When new employees join Uber, they are asked to subscribe to 14 core company values, including making bold bets, being "obsessed" with

## Migrants Hide, Fearing Capture on 'Any Corner'

By VIVIAN YEE

No going to church, no going to the store. No doctor's appointments for some, no school for others. No driving, period — not when a broken taillight could deliver the driver to Immigration and Customs Enforcement.

It is happening in the Central Valley of California, where undocumented immigrants risk the

**IMMIGRATION** A police department worries a crackdown will harm work to fight gangs. PAGE A11

**MEXICO** The secretary of state pays a visit at a time of rising tensions. PAGE A15

Phoenix's Isaac School District, where 13 Latino students have dropped out in the past two

years.

If deportation has always been a threat on paper for the 11 million people living in the country illegally, it rarely imperiled those who did not commit serious crimes. But with the Trump administration intent on curbing illegal immigration — two memos outlining the federal government's plans to accelerate deportations were released Tuesday, another step toward making good on

## TRUMP RESCINDS OBAMA DIRECTIVE ON BATHROOM USE

ENTERING CULTURE WARS

### Question of Transgender Rights Splits DeVos and Sessions

This article is by Jeremy W. Peters, Jo Becker and Julie Hirschfeld Davis.

WASHINGTON — President Trump on Wednesday rescinded protections for transgender students that had allowed them to use bathrooms corresponding with their gender identity, overruling his own education secretary and placing his administration firmly in the middle of the culture wars that many Republicans have tried to leave behind.

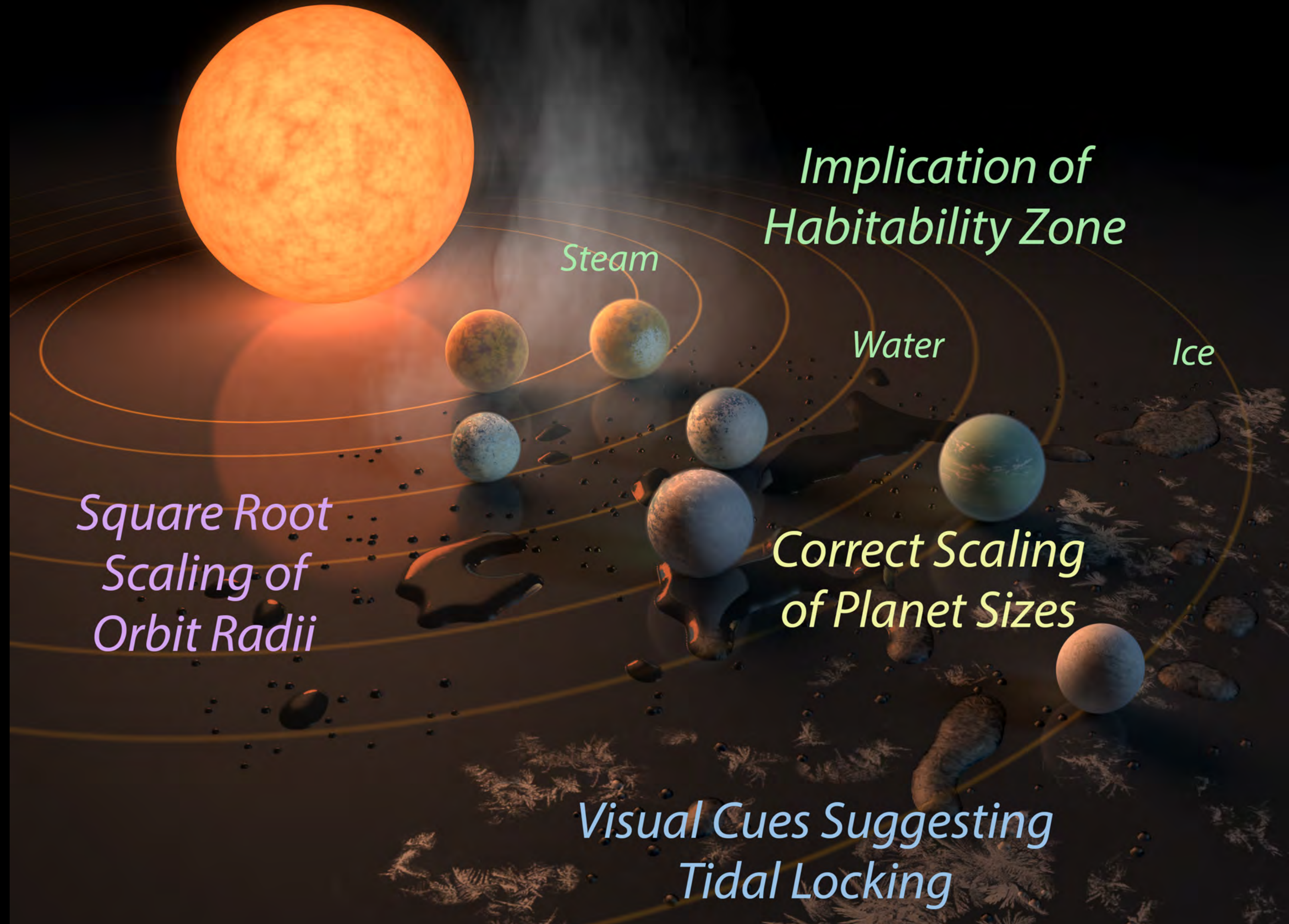
In a joint letter, the top civil rights officials from the Justice Department and the Education Department rejected the Obama administration's position that nondiscrimination laws require schools to allow transgender students to use the bathrooms of their choice.

That directive, they said, was improperly and arbitrarily devised, "without due regard for the primary role of the states and local school districts in establishing educational policy."

The question of how to address the "bathroom debate," as it has become known, opened a rift inside the Trump administration.



*Accurate color  
temperature*



# nature

THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE

Seven potential  
Earth-like worlds  
orbiting low-mass  
star TRAPPIST-1

PAGES 421 & 456

## PLANET SUITE

EPITRANSCRIPTOMICS

### CAUGHT IN TRANSLATION

Tracking the chemical  
tags on RNA

PAGES 406 & 503

REPRODUCIBILITY

### PUT TO THE TEST

Add independent preclinical  
trials to biomedical papers

PAGE 409

CLIMATE SCIENCE

### A MODEL FOR MELTING

Predictability of ice ages  
affirmed

PAGES 419, 427 & 468

[NATURE.COM/NATURE](https://www.nature.com/nature)

23 February 2017 £10

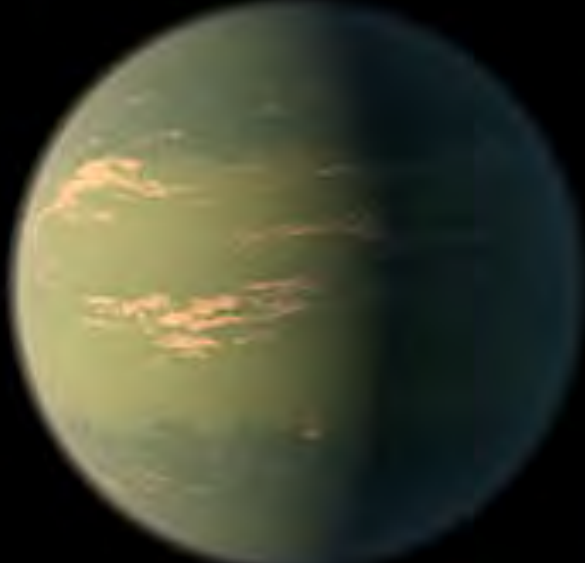
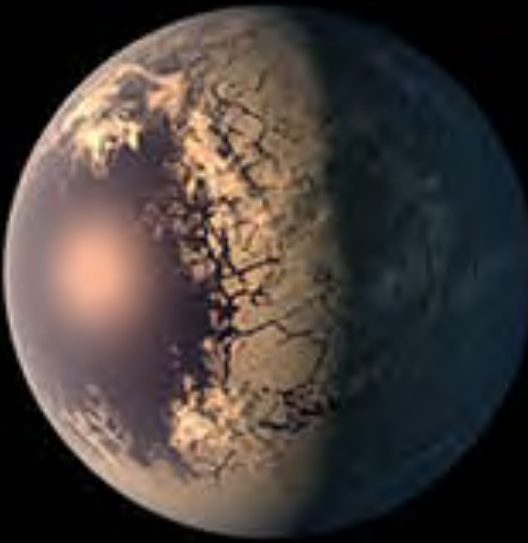
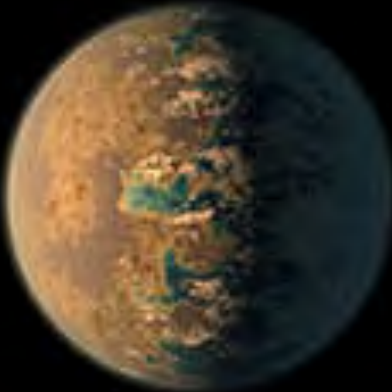
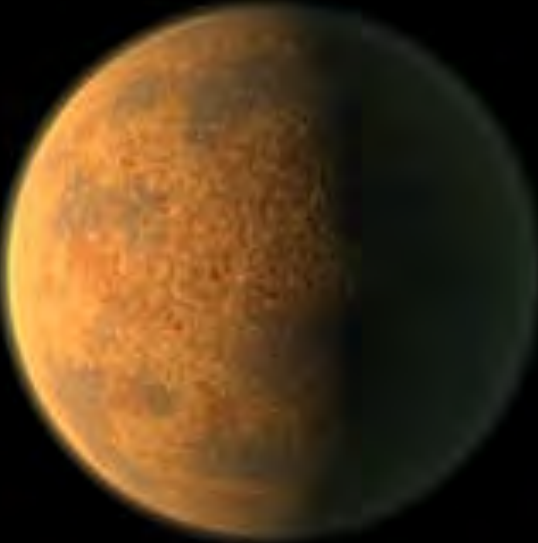
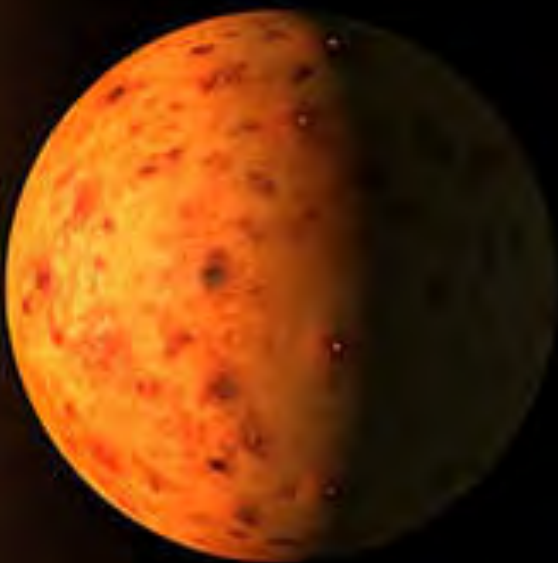
Vol. 542, No. 7642







February, 2017



February, 2018





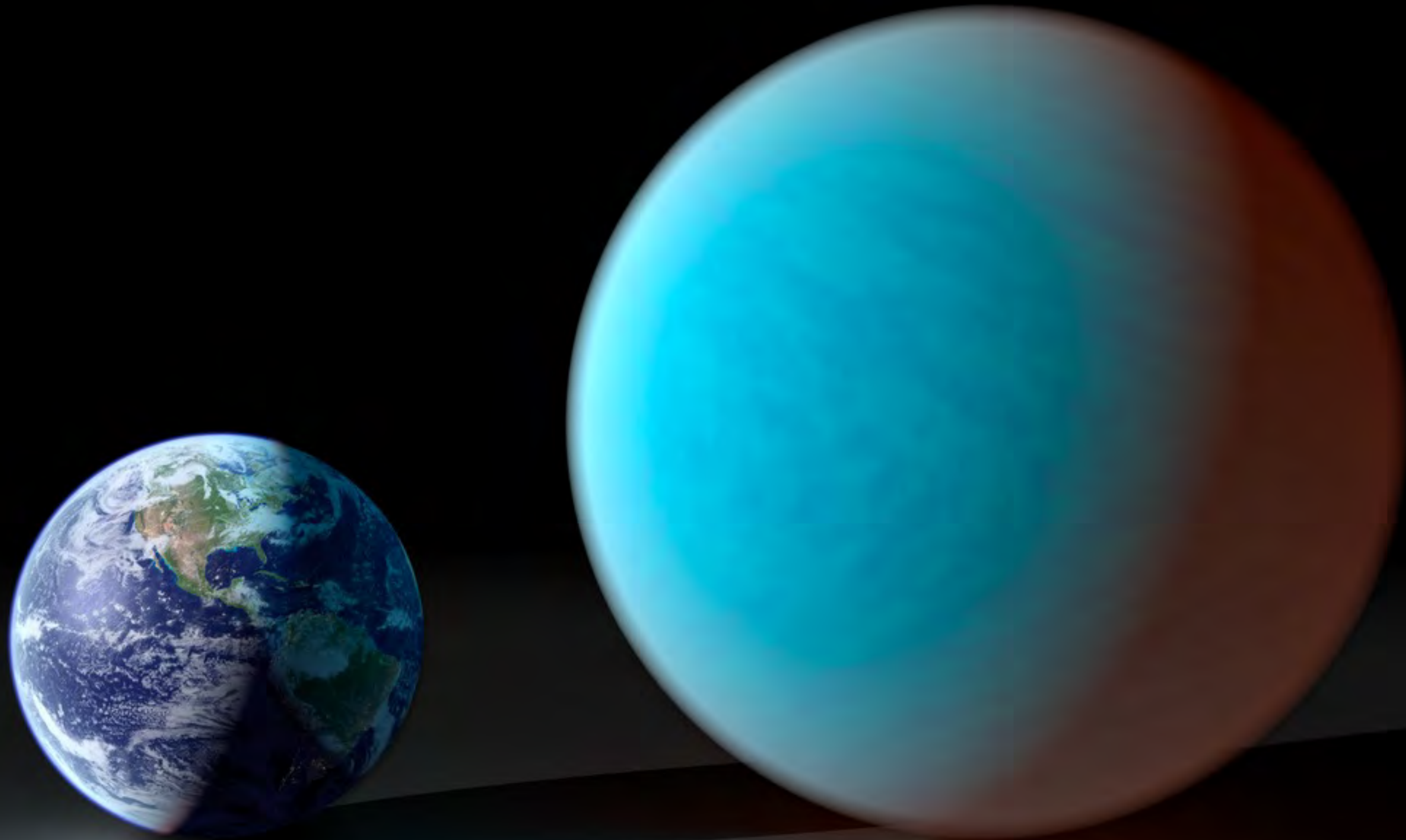
PLANET HOP FROM  
**TRAPPIST-1e**



VOTED BEST "HAB ZONE" VACATION WITHIN 12 PARSECS OF EARTH

**55 Cancri e**

(2011)



**55 Cancri e**

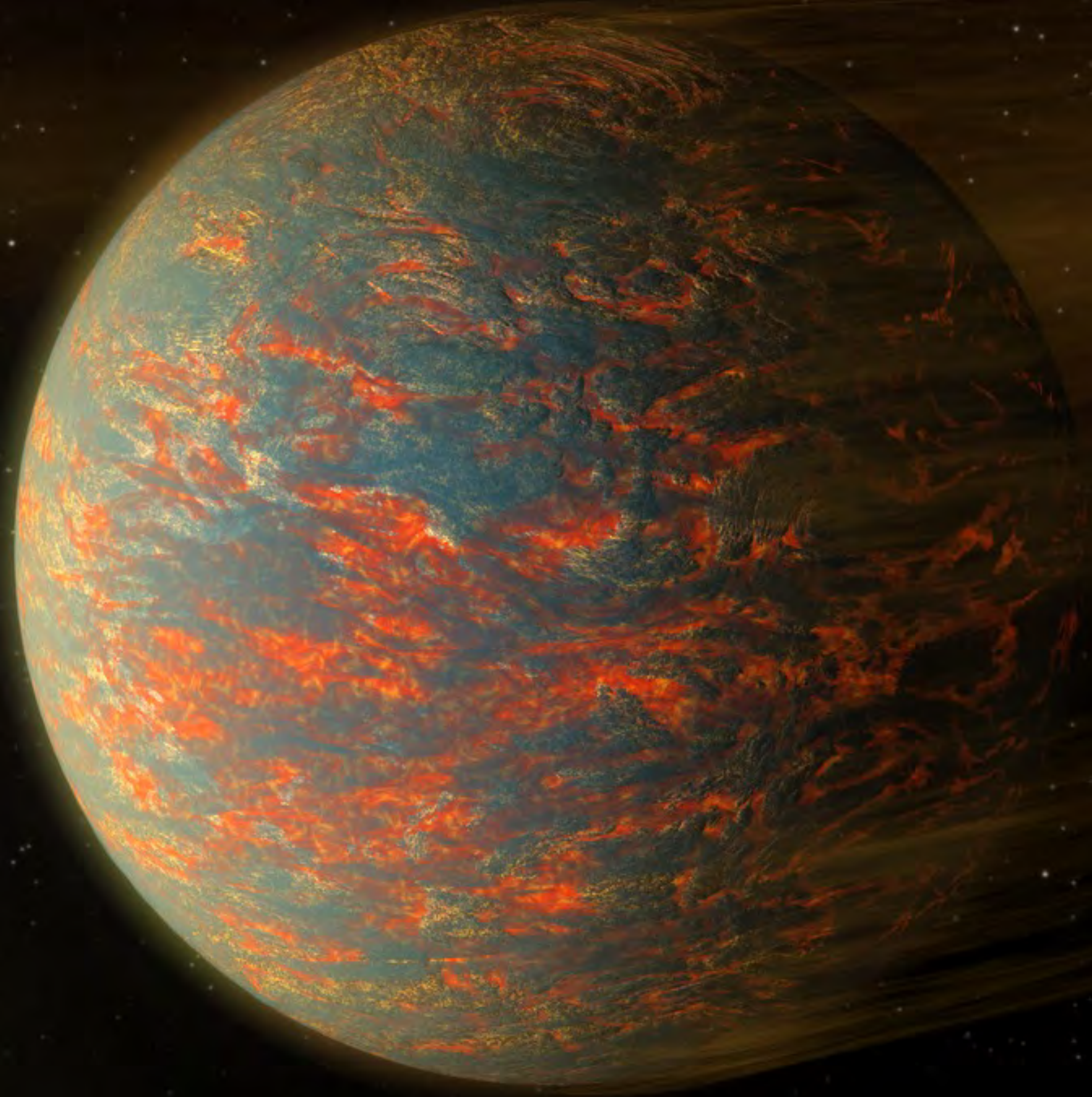


(2015)



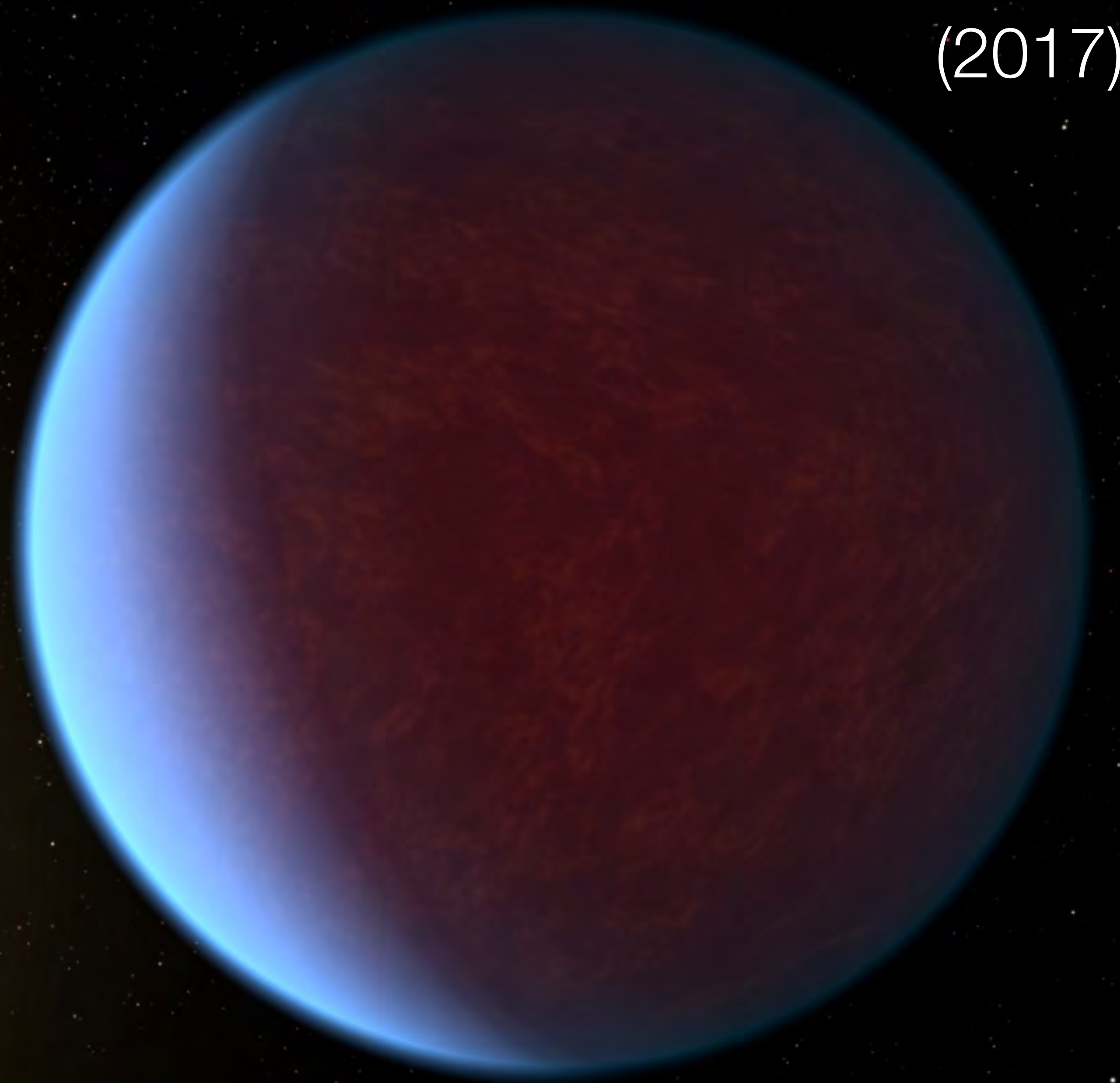
**55 Cancri e**

(2016)

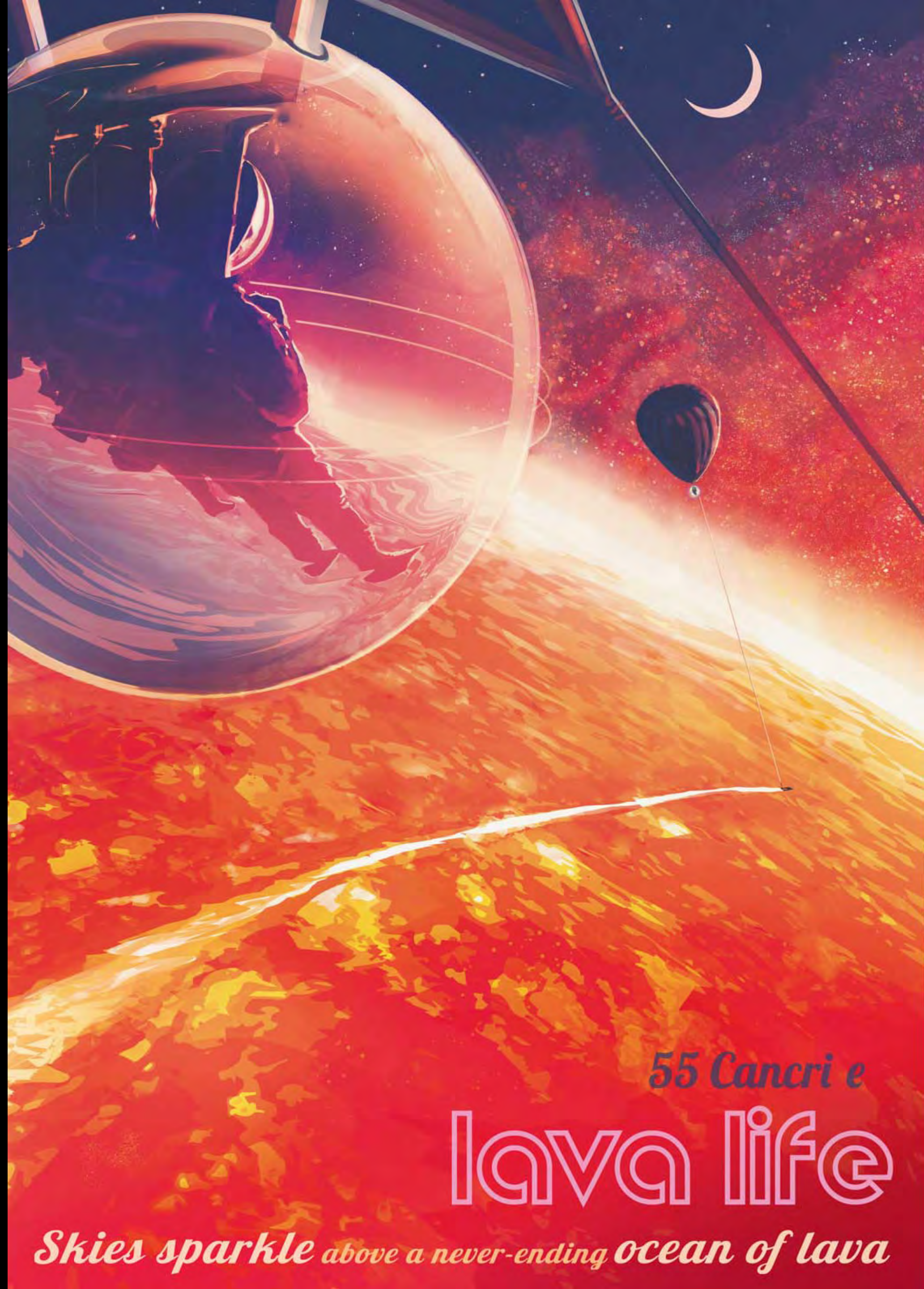


**55 Cancri e**

(2017)







*55 Cancri e*

# lava life

*Skies sparkle above a never-ending ocean of lava*

