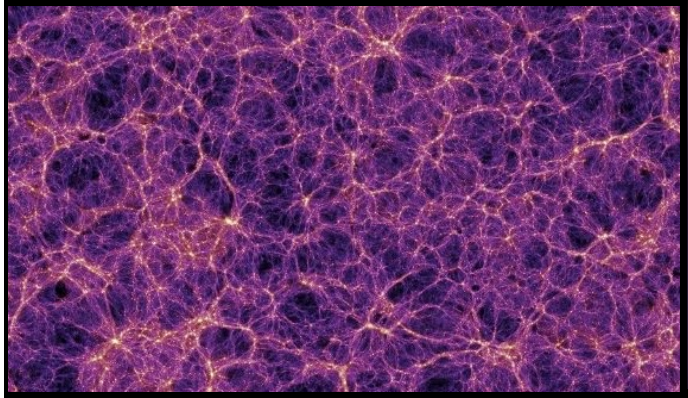
JOHN O'MEARA, W. M. KECK OBSERVATORY

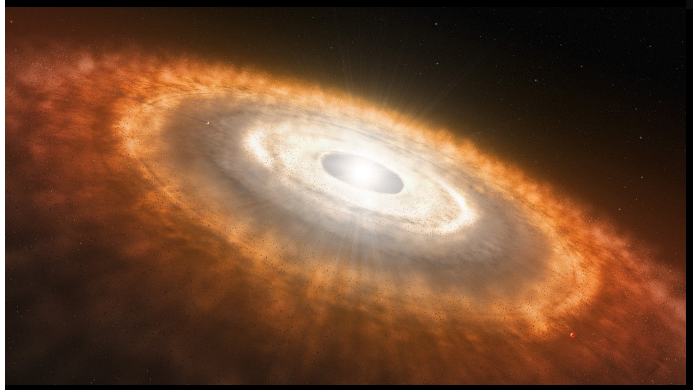
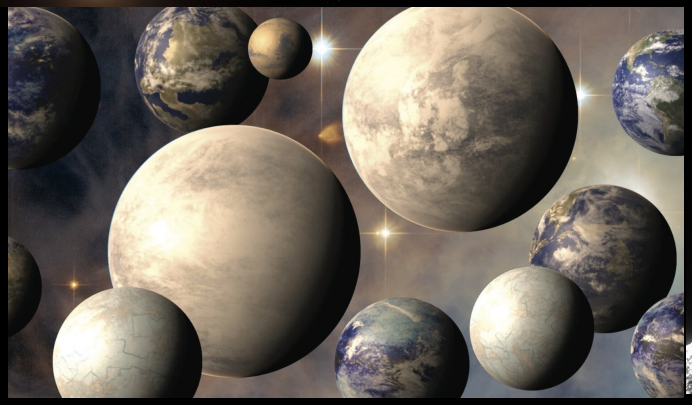
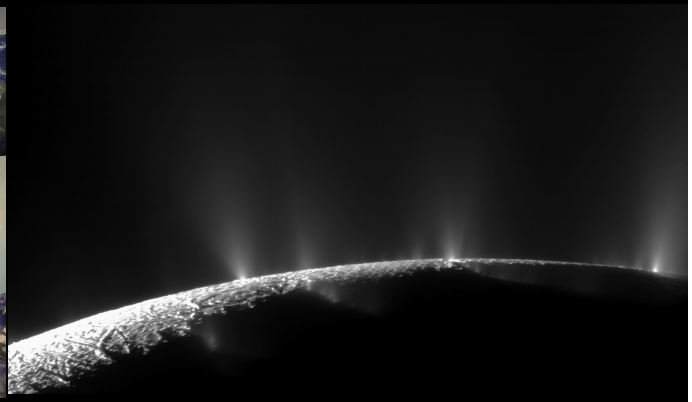
FROM SCIENCE TO MISSION AND BACK AGAIN

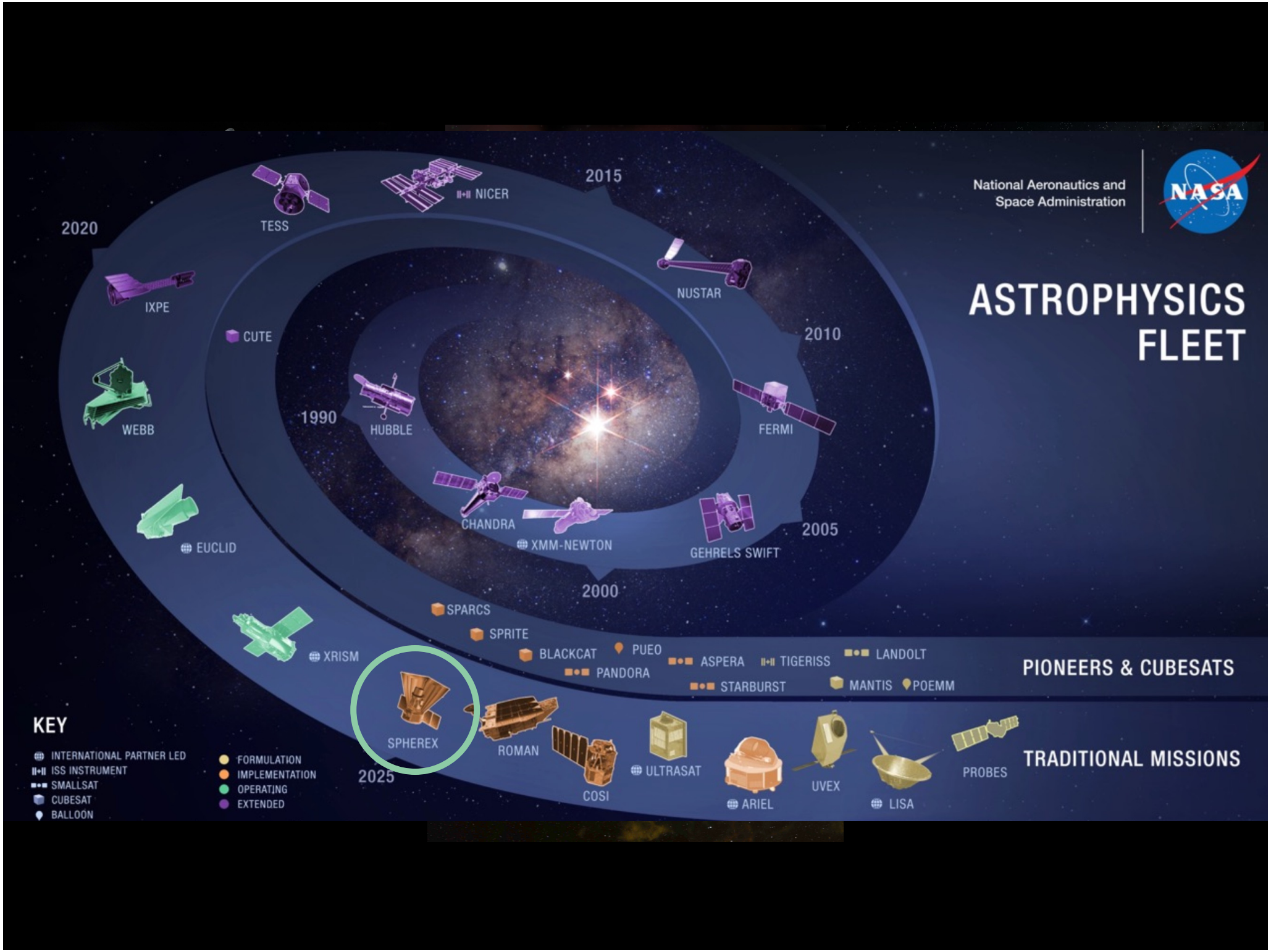
ASTROPHYSICS DRIVING QUESTIONS

- Are we alone?
- How did we get here?
- How does the universe work?




HOW DID OUR UNIVERSE ENABLE LIFE?


National Aeronautics and Space Administration
NASA
ASTROPHYSICS FLEET
2020
2015
2010
2005
2000
1990
TESS
NICER
IXPE
NUSTAR
CUTE
WEBB
HUBBLE
FERMI
CHANDRA
XMM-NEWTON
GEHRELS SWIFT
EUCLID
SPARCS
SPRITE
XRISM
BLACKCAT
PUEO
ASPERA
TIGERISS
LANDOLT
PANDORA
STARBURST
MANTIS
POEMM
PIONEERS & CUBESATS
SPHEREX
ROMAN
COSI
ULTRASAT
ARIEL
UVEX
LISA
PROBES
TRADITIONAL MISSIONS
KEY
INTERNATIONAL PARTNER LED
ISS INSTRUMENT
SMALLSAT
CUBESAT
BALLOON
FORMULATION
IMPLEMENTATION
OPERATING
EXTENDED

DISCLAIMER #1

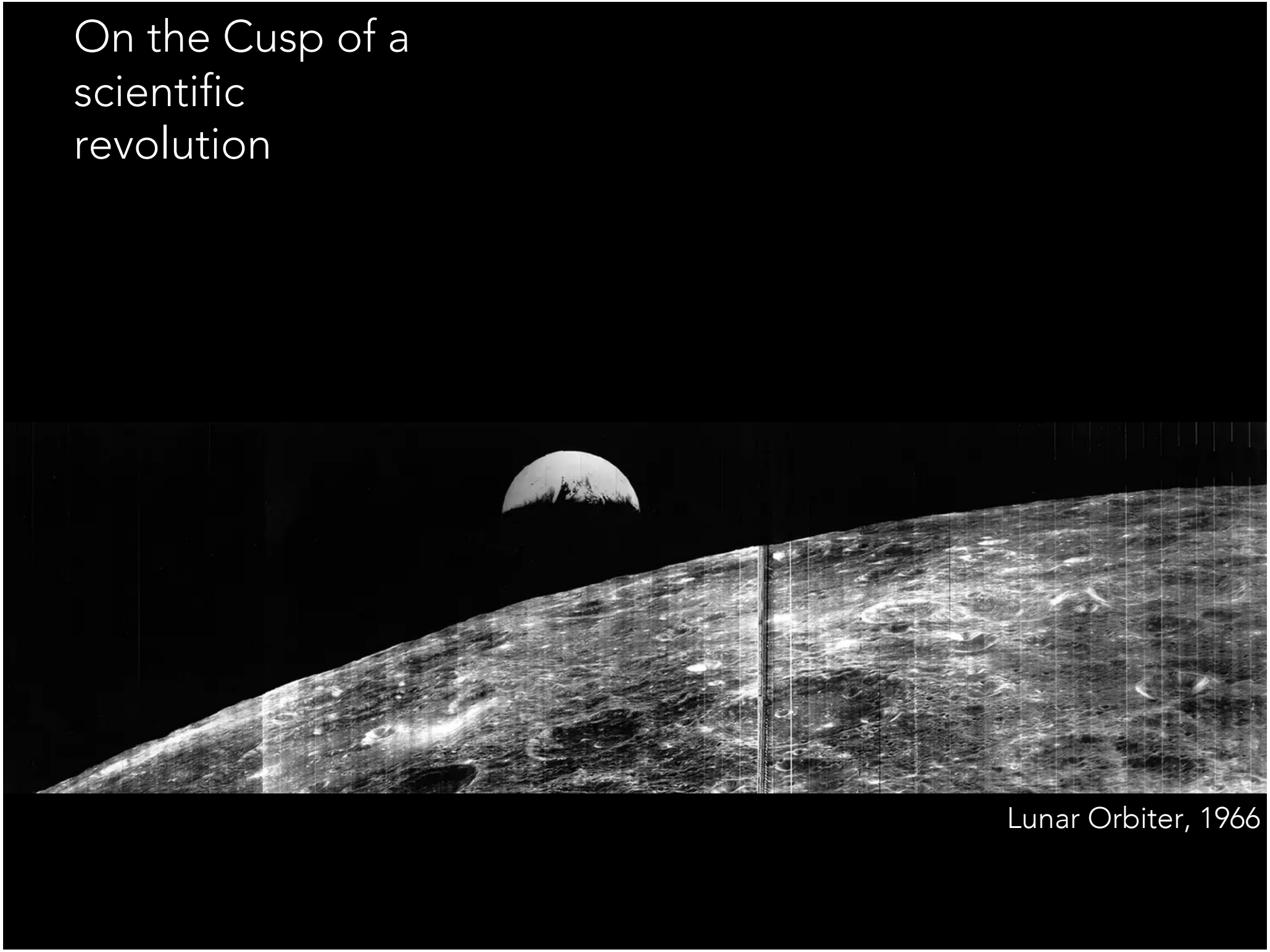
John is not a technologist

DISCLAIMER #2

The universe does not care about

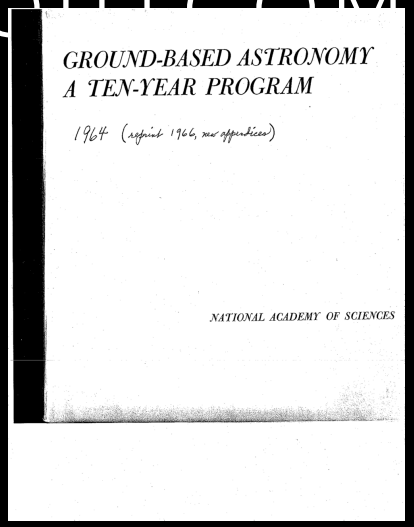
what you think you cannot build

On the Cusp of a scientific revolution

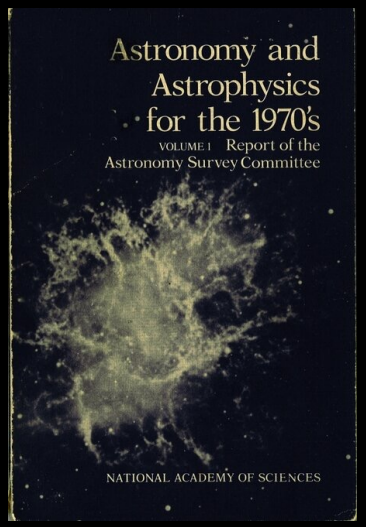


Lunar Orbiter, 1966

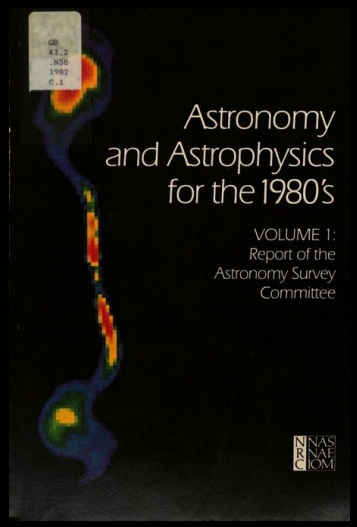
PAST DECADALS & LARGE OUTCOMES



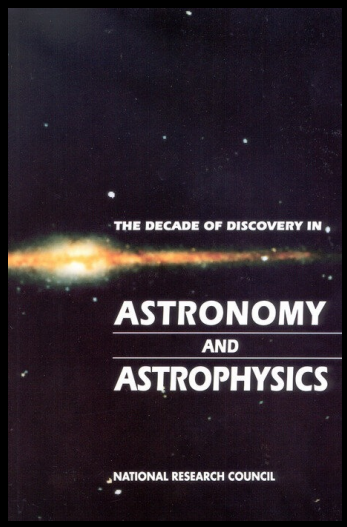
Kitt Peak



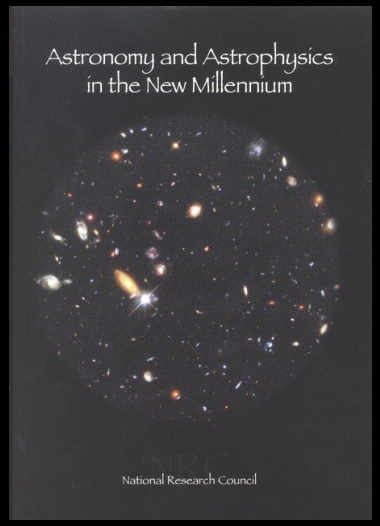
VLA, HST



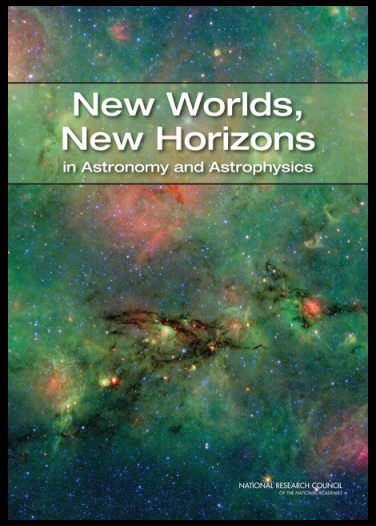
Chandra, VLBA



Spitzer, SOFIA, ALMA

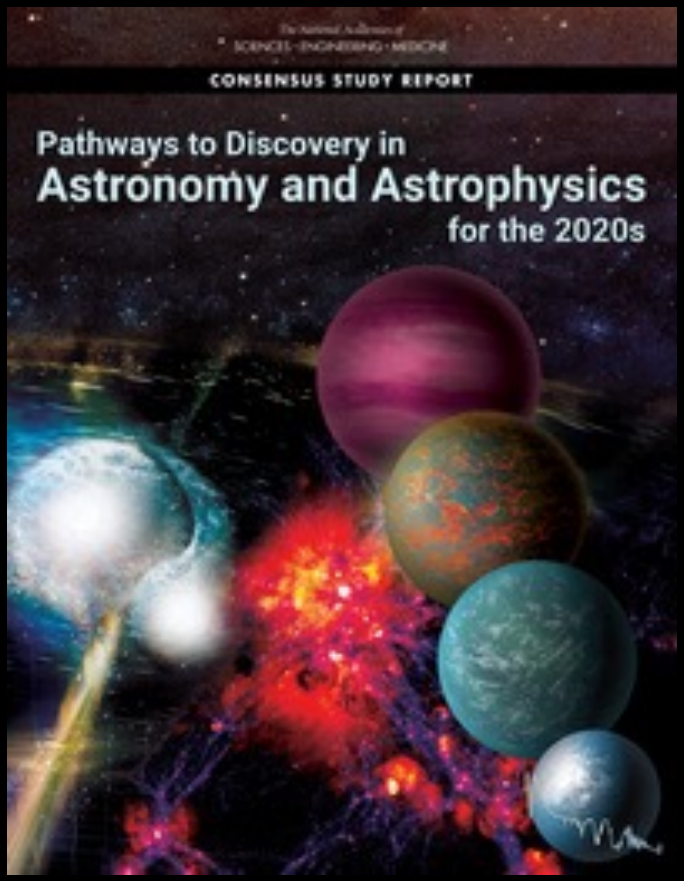


JWST, ALMA



LSST, WFIRST

PATHWAYS TO DISCOVERY IN ASTRONOMY AND ASTROPHYSICS IN FOR THE 2020S



ASTRO 2020: THE SCIENTIFIC FOUNDATIONS

Worlds and Suns in Context

Priority Area: Pathways to Habitable Worlds

Understanding the connections between stars and the worlds that orbit them, from nascent disks of dust and gas through formation and evolution, is an important scientific goal for the next decade. The effort to identify habitable Earth-like worlds in other planetary systems and search for the biochemical signatures of life will play a critical role in determining whether life exists elsewhere in the universe.

KEY RECOMMENDATIONS:

New Messengers and New Physics

Priority Area: New Windows on the Dynamic Universe

Over the next decade, a range of complementary observations—from radio to gamma rays, gravitational waves, neutrinos, and high-energy particles—will enable investigations into the most energetic processes in the universe and address larger questions about the nature of dark matter, dark energy, and cosmological inflation. These growing capabilities will enable closer study of neutron stars, white dwarfs, black hole collisions, stellar explosions, and the birth of our universe.

KEY RECOMMENDATIONS:

Cosmic Ecosystems

Priority Area: Unveiling the Drivers of Galaxy Growth

Research in the coming decade will revolutionize our understanding of the origins and evolution of galaxies, from the cosmic webs of gas that feed them to the formation of stars. New observational capabilities across the electromagnetic spectrum along with computation and theory will help resolve the rich workings of galaxies on all scales.

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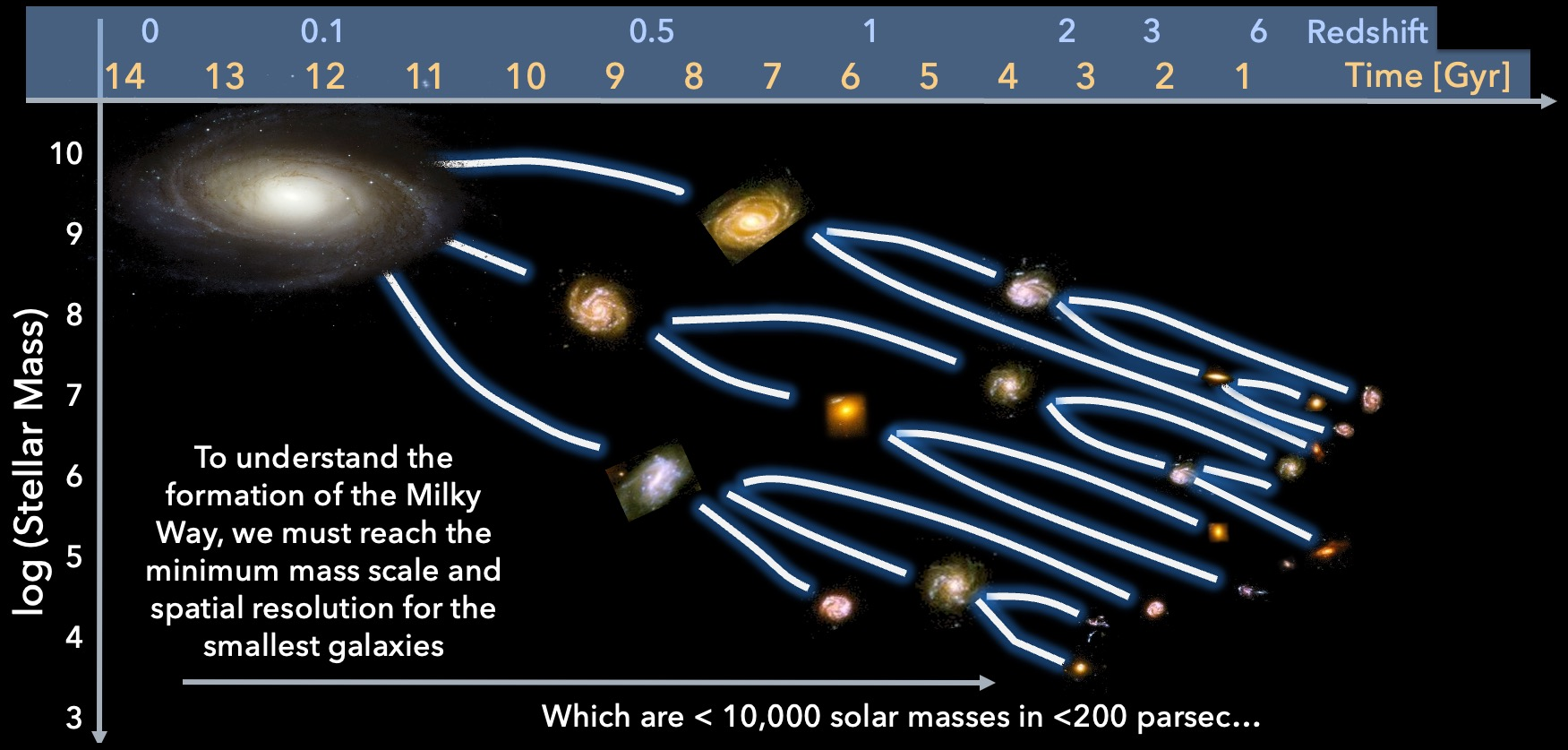
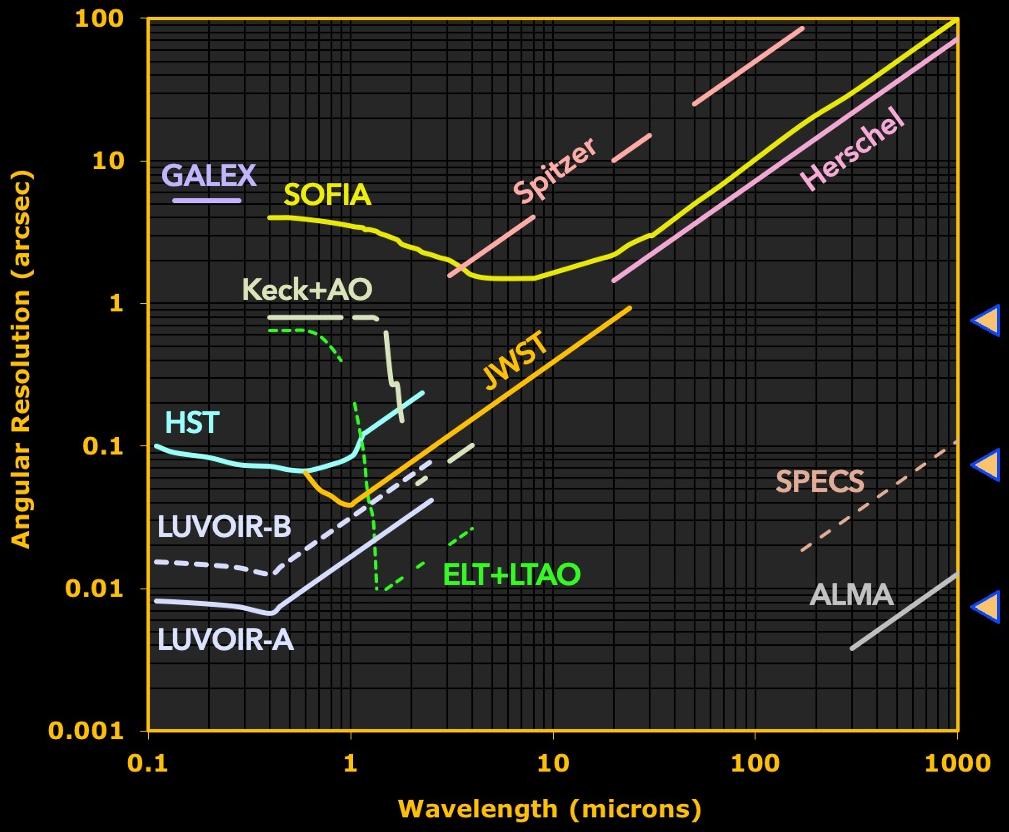
KEY RECOMMENDATIONS:

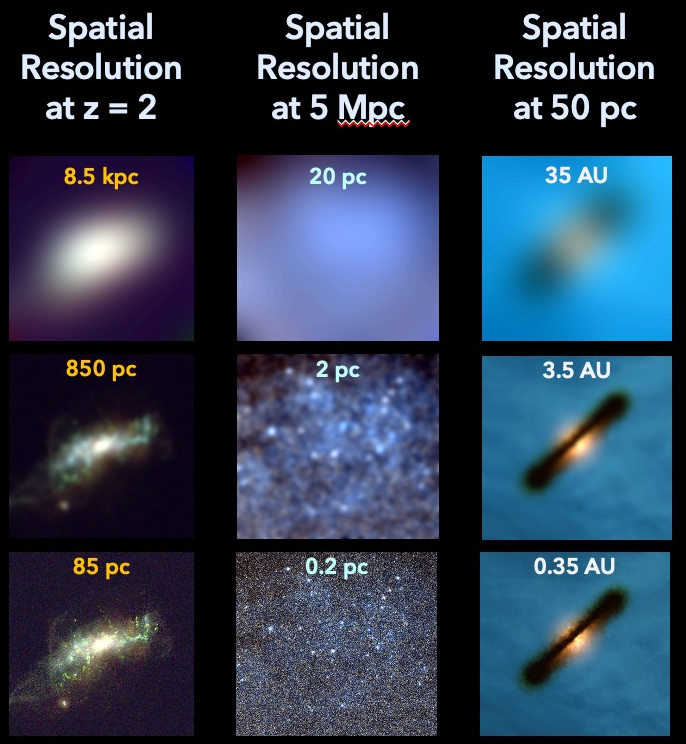
- How do galaxies fuel stars, and keep fueling them?
- How do galaxies go from star-forming to red and dead?
- How can we explain what JWST is seeing?

THE COSMIC LANDSCAPE – MILKY WAY ASSEMBLY

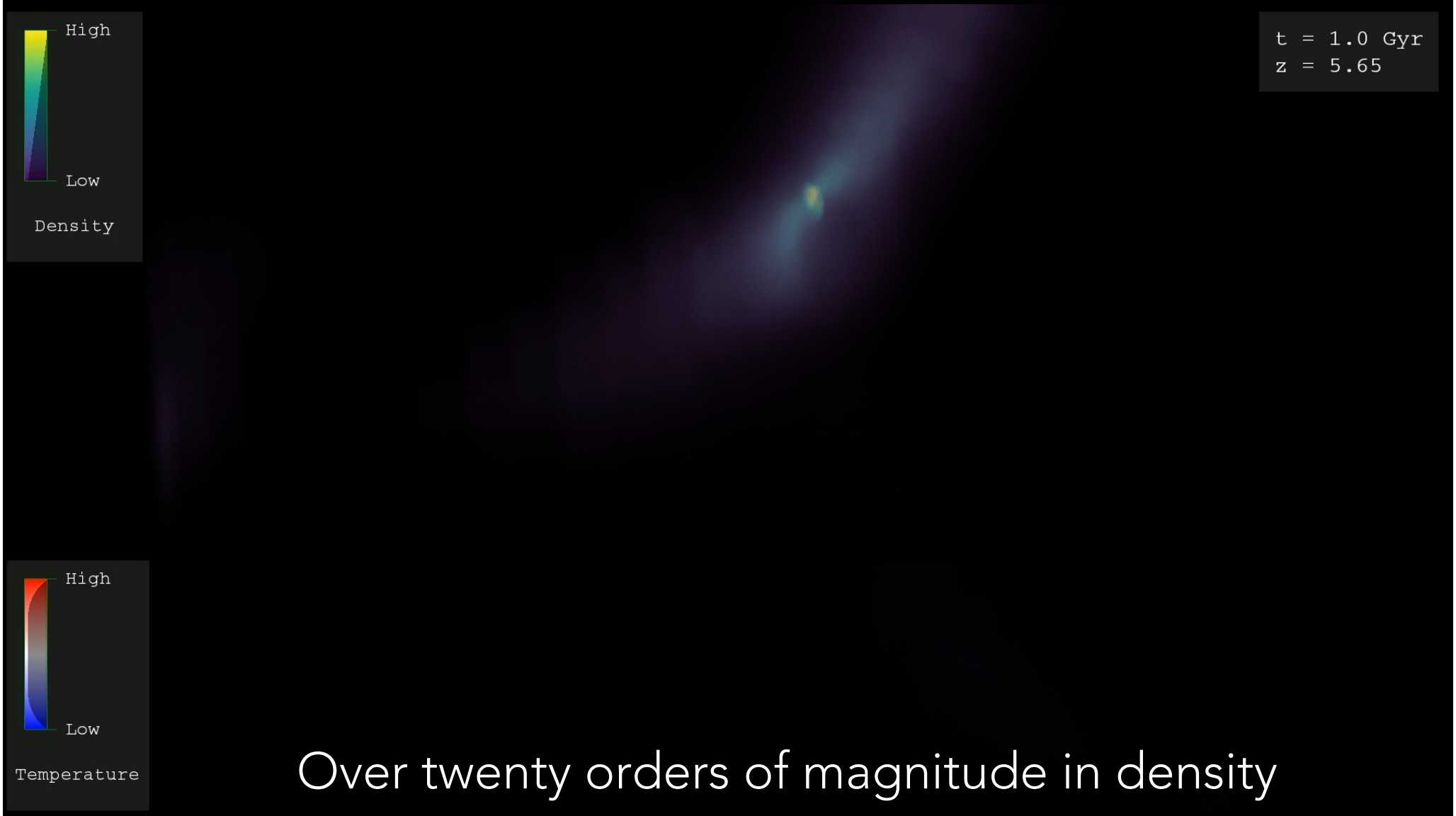


THE ESSENTIAL RESOLUTION

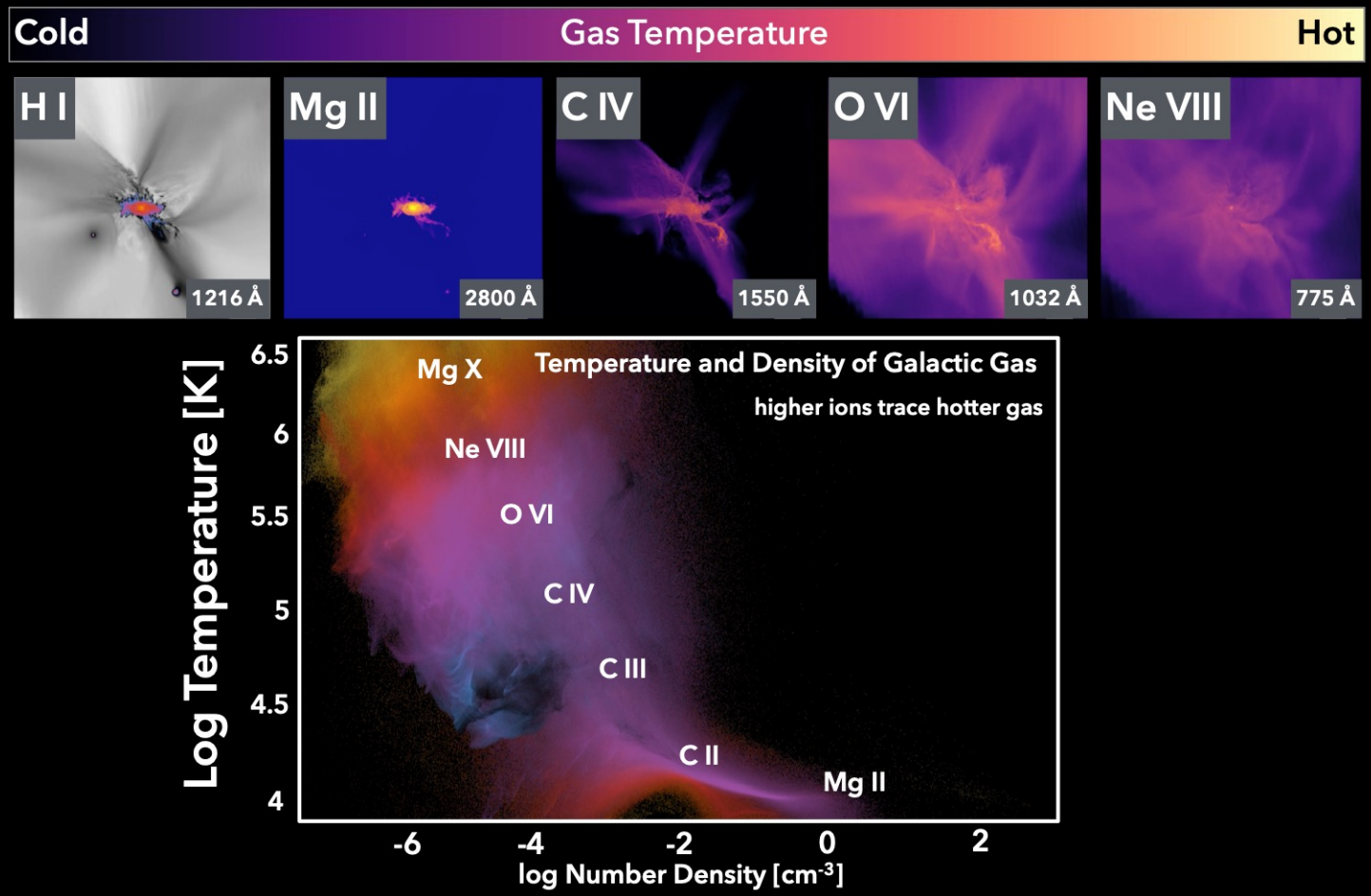




Six orders of magnitude in temperature

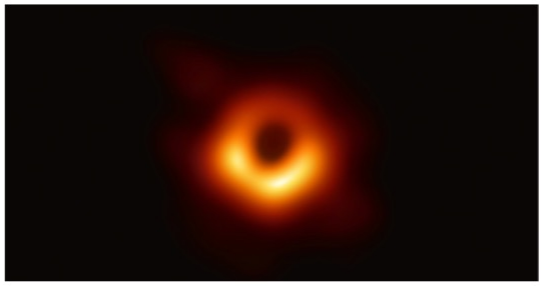


Over twenty orders of magnitude in density


Cold
Gas Temperature
Hot
H I
1216 Å
Mg II
2800 Å
C IV
1550 Å
O VI
1032 Å
Ne VIII
775 Å
Temperature and Density of Galactic Gas
higher ions trace hotter gas
Mg X
Ne VIII
O VI
C IV
C III
C II
Mg II
Log Temperature [K]
6.5
6
5.5
5
4.5
4
-6
-4
-2
0
2
log Number Density [cm-3]

THE CHALLENGES

- Need to measure both weak atomic and molecular features in absorption, often at high spectral resolution
- Want to measure very low surface brightness emission from low density, warm gas
- Key wavelengths are the X-Ray, UV, IR, Mid IR, radio



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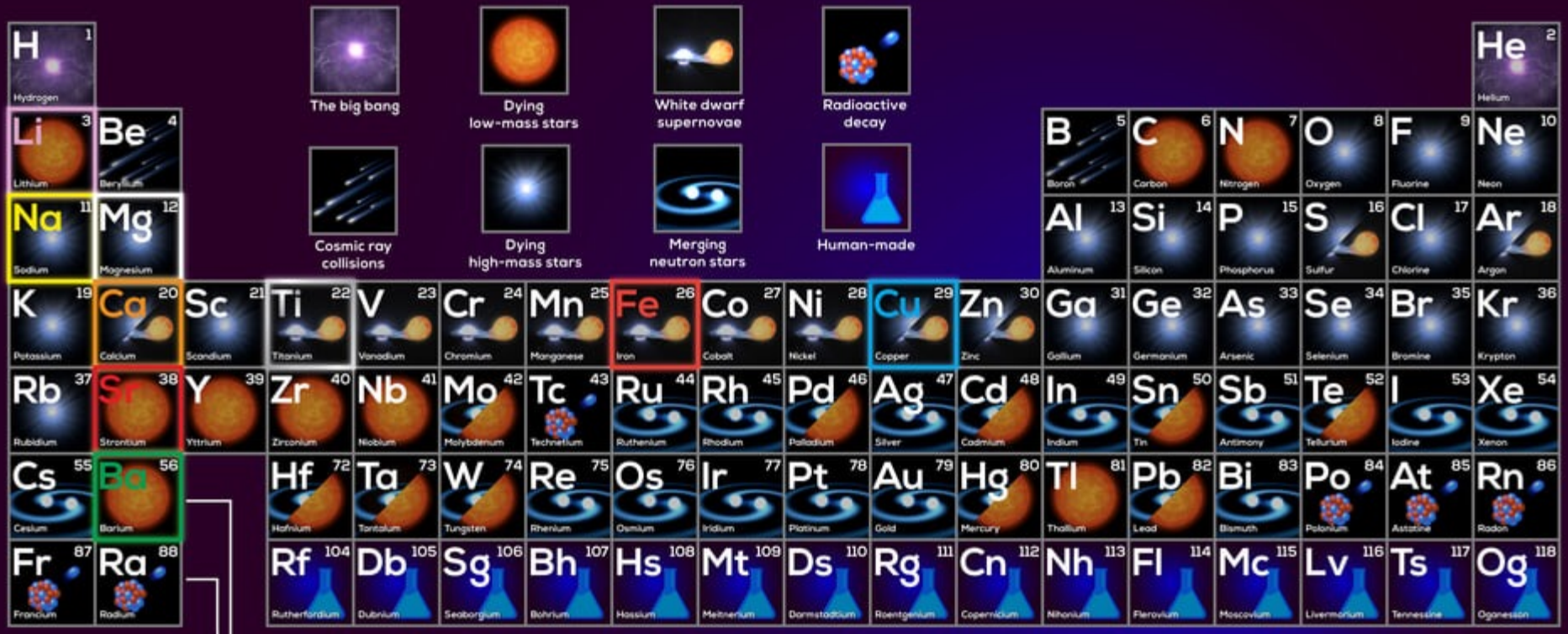
KEY RECOMMENDATIONS:

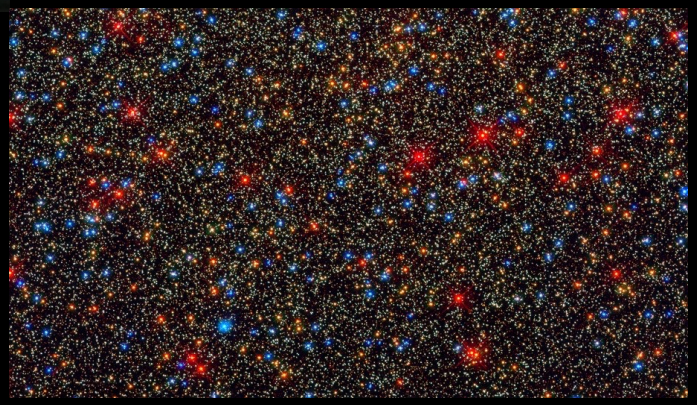
- What is the nature of dark matter and dark energy?
- How did the periodic table arise?
- How does the universe work in extreme environments?

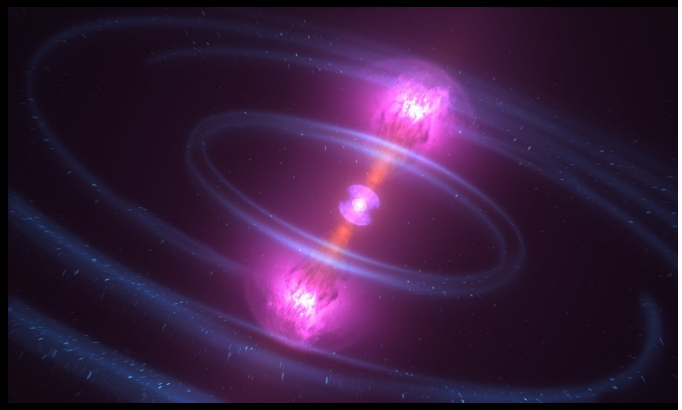
DEATH SPIRAL/LIFE SPIRAL

Origins of the Elements



This periodic table depicts the primary source on Earth for each element. In cases where two sources contribute fairly equally, both appear.





Following the Elements Over Cosmic Time

THE CHALLENGES

- Rapid response means many things, and all are hard (fast slew, fast shutter, fast decision making)
- Coordination of multiple missions and capabilities
- Key wavelengths are the X-Ray, UV, IR, Mid IR, radio….and non EM

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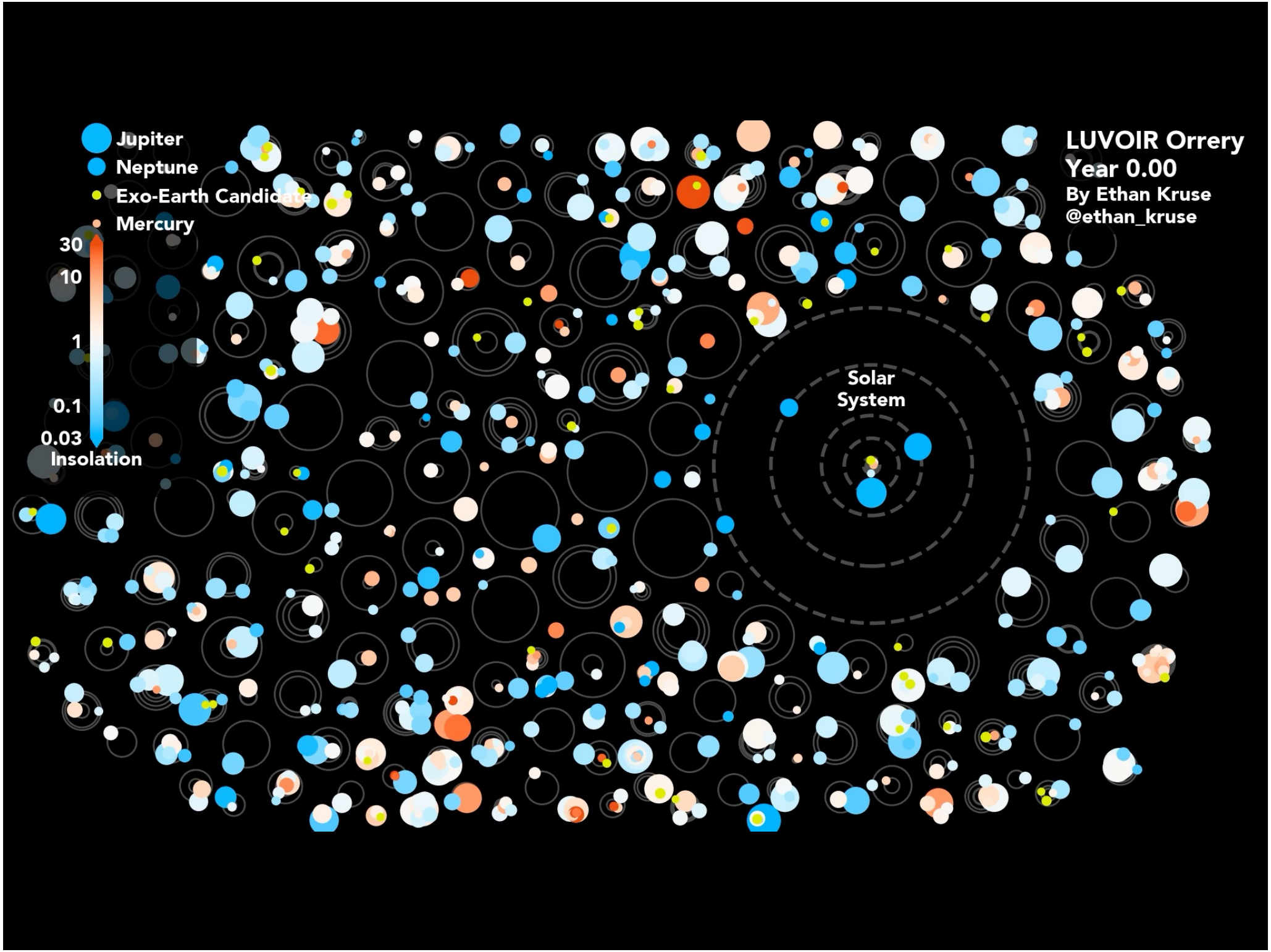
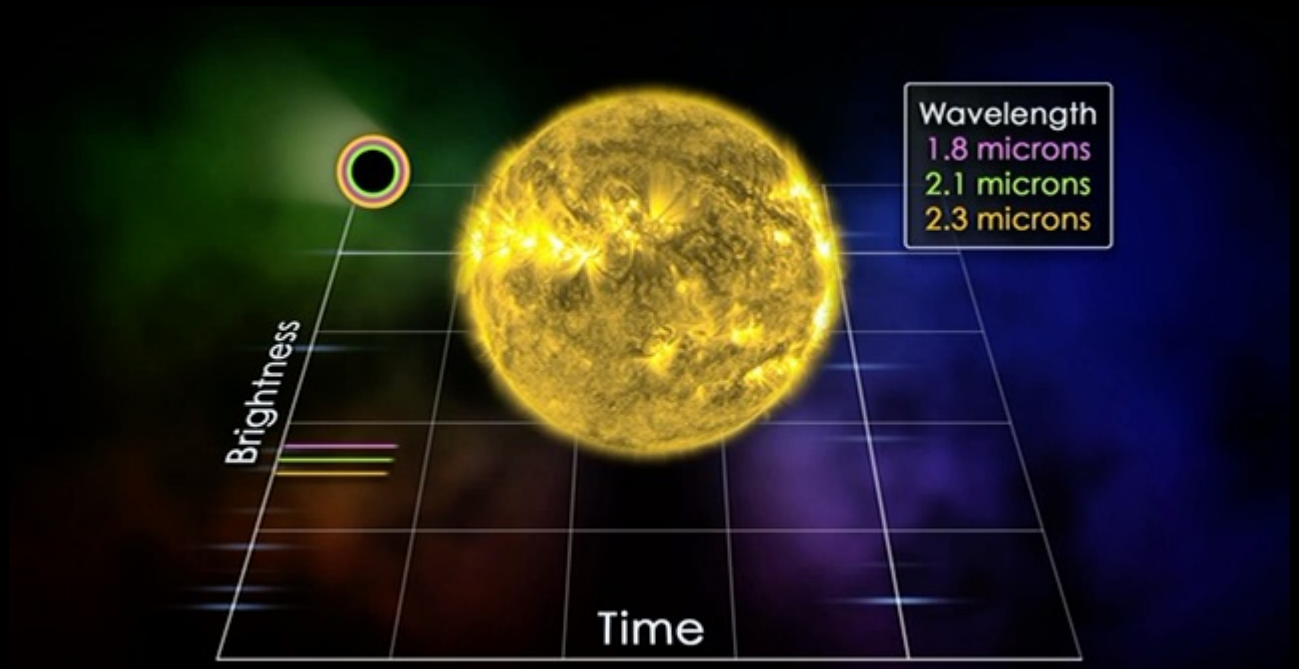
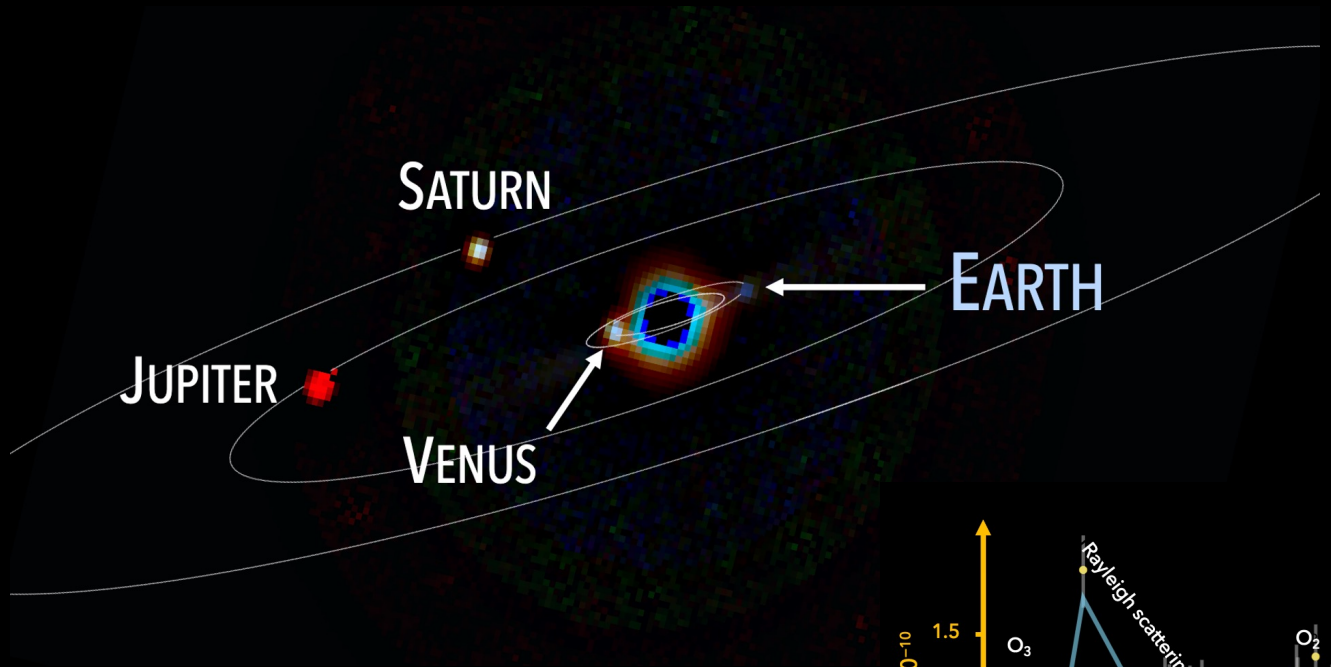
KEY RECOMMENDATIONS:

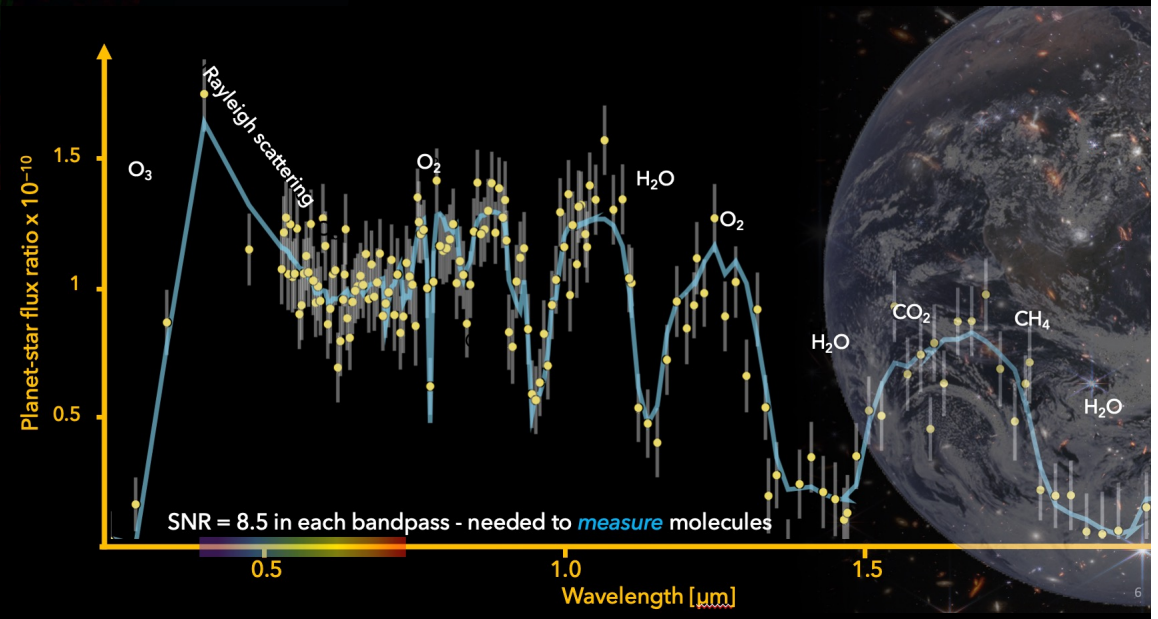
- What is our Solar System's cosmic context?
- Is Earth unique? Common?
- Life?


Jupiter
Neptune
Exo-Earth Candidate
Mercury
30
10
1
0.1
0.03
Insolation
Solar System
LUVOIR Orrery
Year 0.00
By Ethan Kruse
@ethan_kruse

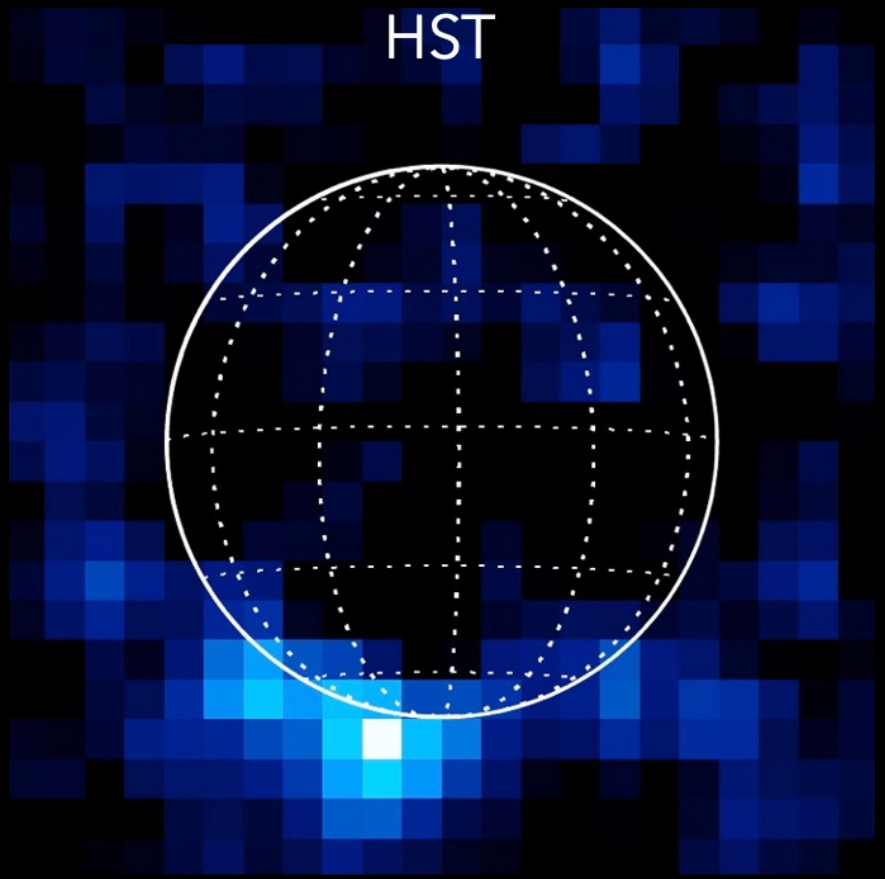

Wavelength
1.8 microns
2.1 microns
2.3 microns
Brightness
Time

The Search for Living Worlds





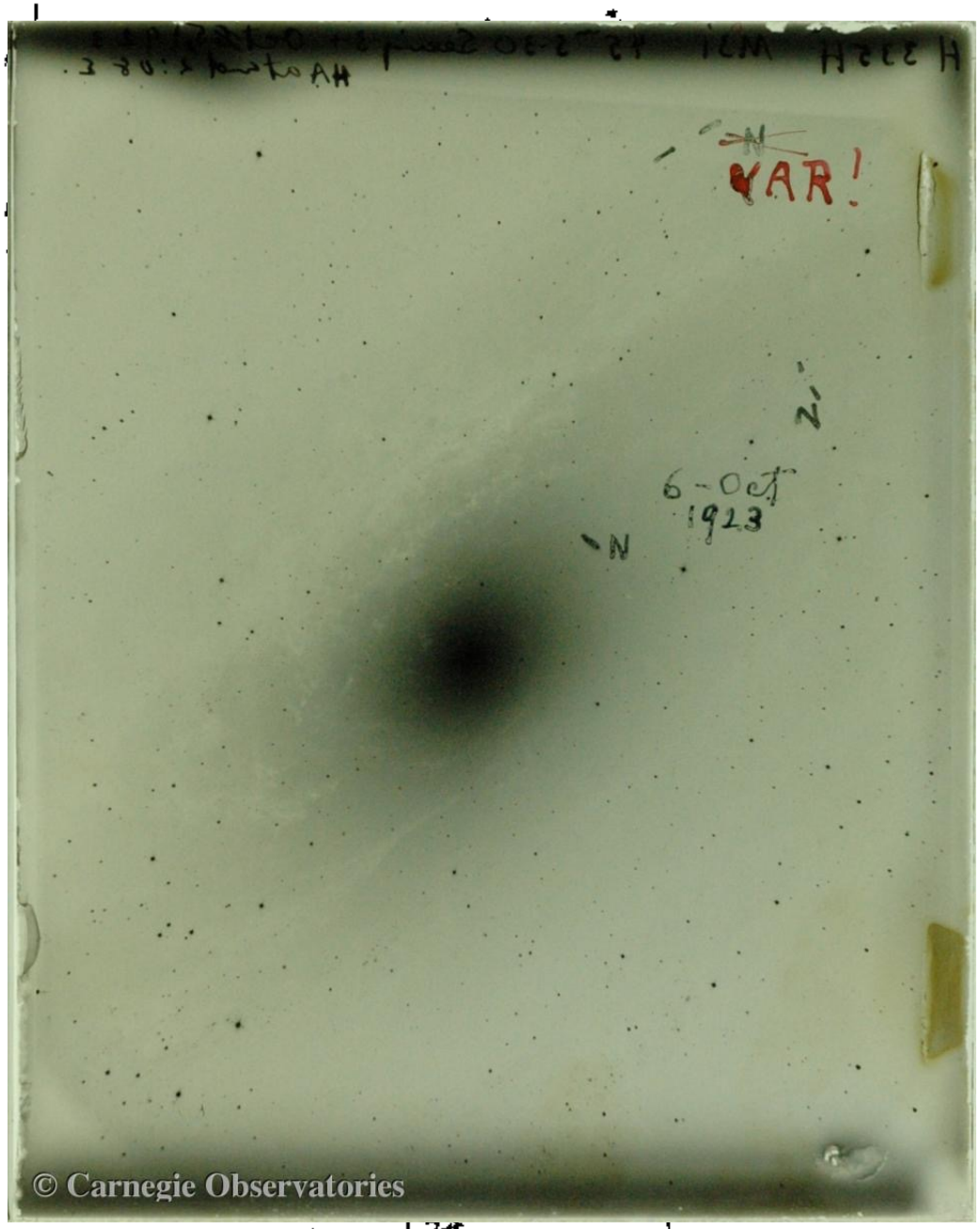
EUROPA IN ULTRAVIOLET

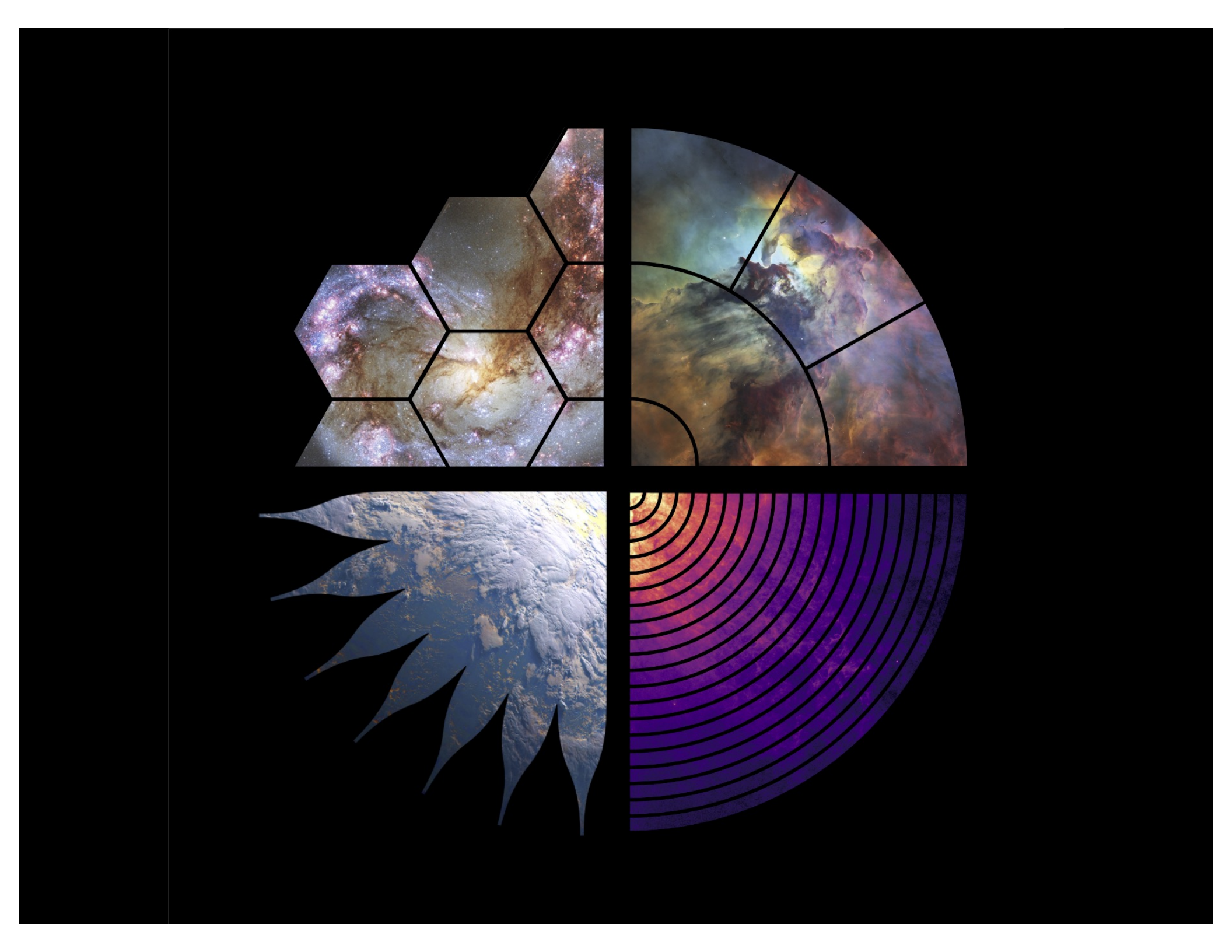


THE CHALLENGES

- Star/planet contrasts on the order of a billion or higher
- Extremely small star/planet separations on the sky
- Key wavelengths UV -> Mid-IR

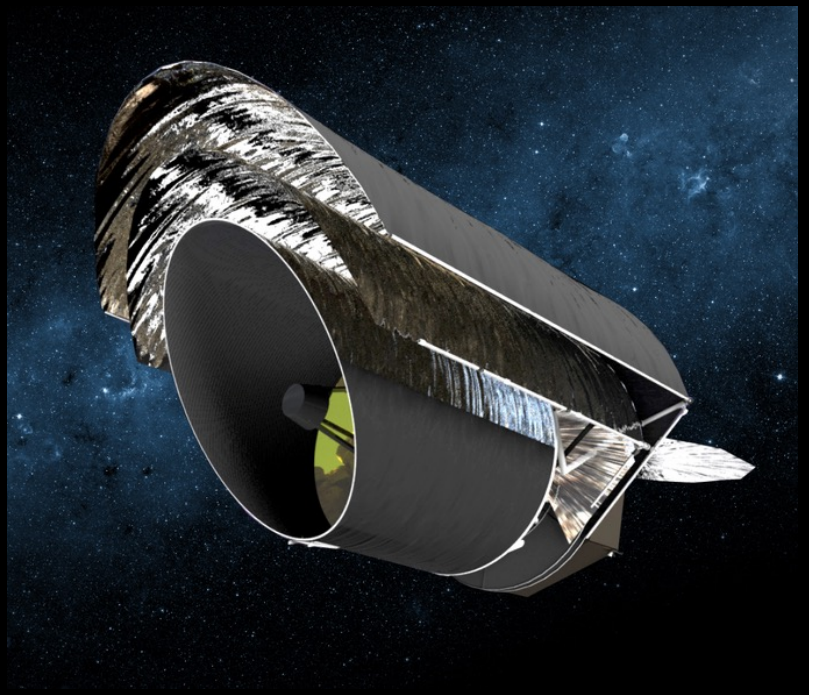
THE FUTURE OF THE FLEET



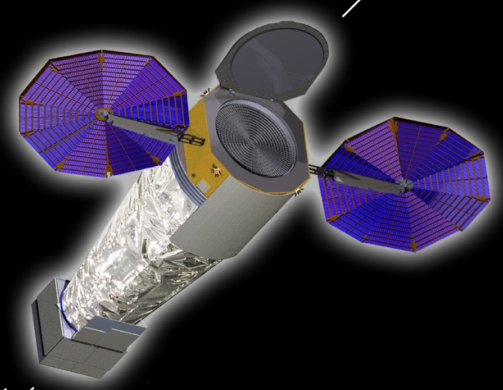


ORIGINS

- ~6m primary (keystone)
- Diffraction limited at 30μ
- Operates at 4.5K
- Mid infrared transit spectrometer, R~100 from 5-30μ
- FIR medium resolution multi-object spectrometer from 30-600μ and R~300 or 40,000
- FIR broadband imager/polarimeter at 50, 250μ



LYNX



LYNX MIRROR ASSEMBLY

0.5'' on-axis PSF, 2m² effective area at 1 keV, sub-arcsec PSF over a 22'×22' field of view.

HIGH DEFINITION X-RAY IMAGER

An active pixel array of fine pixels covering a 22'×22' field of view with subarcsecond imaging and providing moderate spectral resolution.

LYNX X-RAY MICROCALORIMETER

An array of 1'' pixels covering a 5'×5' field of view and providing 3 eV spectral resolution. Two additional arrays are optimized for finer imaging (0.5'' pixels) and higher spectral resolution (0.3 eV in the soft band)

X-RAY GRATING SPECTROMETER

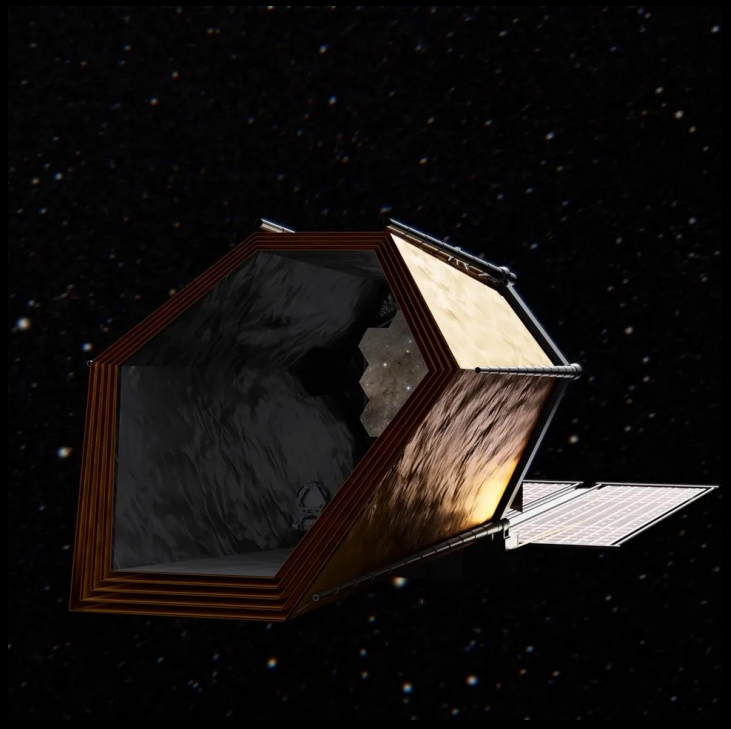
Gratings with resolving power of $R > 5000$ and ~ 4000 cm² of effective area across the critical X-ray emission and absorption lines of C, O, Mg, Ne, and Fe L.

THE MISSION

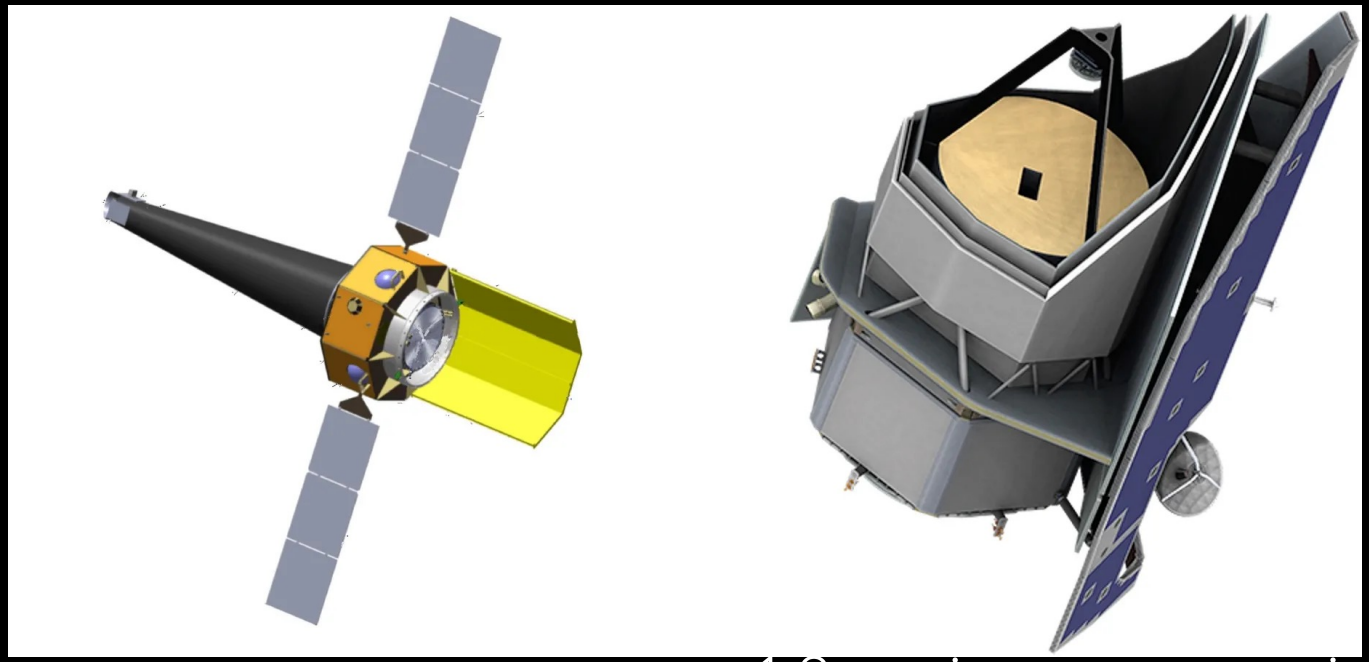
- Orbit: Sun-Earth L2
- Field of regard: 85% of the sky
- Consumables: sized for a 20 year mission
- Data volume: JWST comparable
- Communications: 3 times daily with DSN
- Observing Efficiency: >85%

HWO

- Derived from LUVOIR/HabEx studies
- Currently in pre-Phase A and exploring architecture and science trade spaces
- UVOIR mission requiring very high stability, corona graphic contrast ratio, and spatial resolution



AXIS AND PRIMA



2x2 array of 1.4k by 1.4k CCD detectors for deep Xray imaging

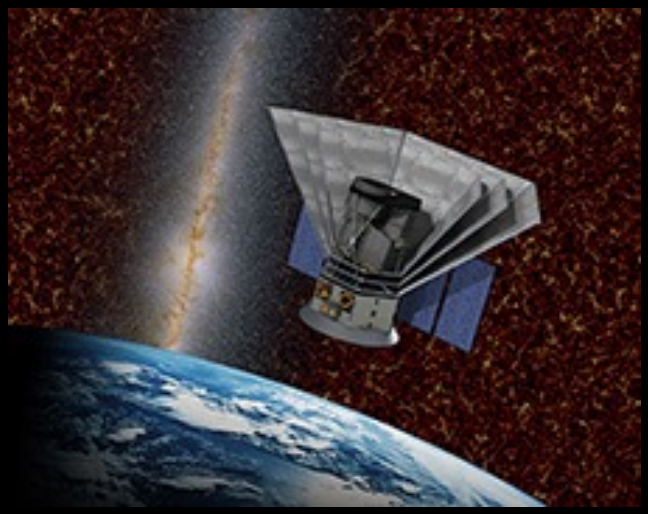
Silicon grazing incidence x-ray optic

1.9m primary, cryogenically cooled

Wide-band spectrometer/polarimeter and imager

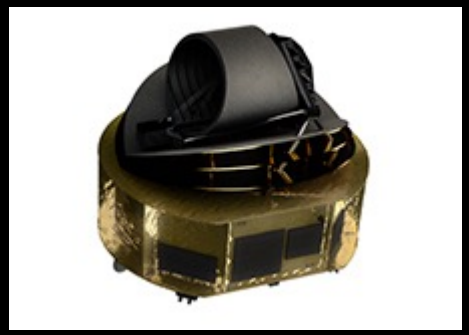
Full band low and narrow bind high resolution spectroscopy

EXPLORERS

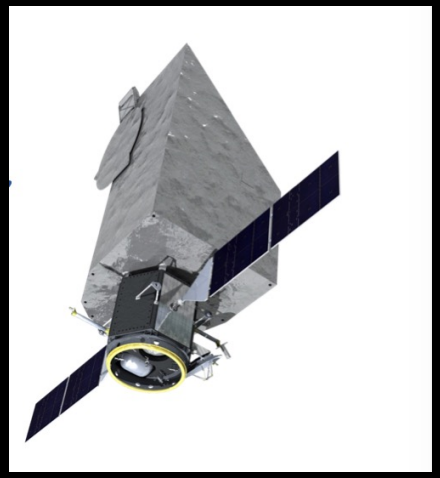


SPHEREx (this week)

COSI (2027)

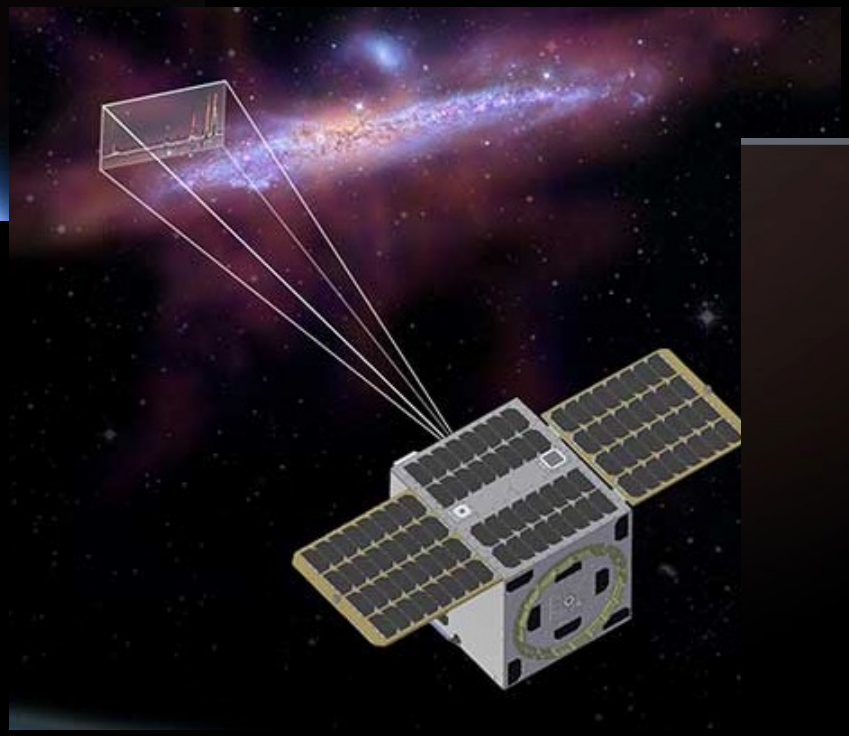


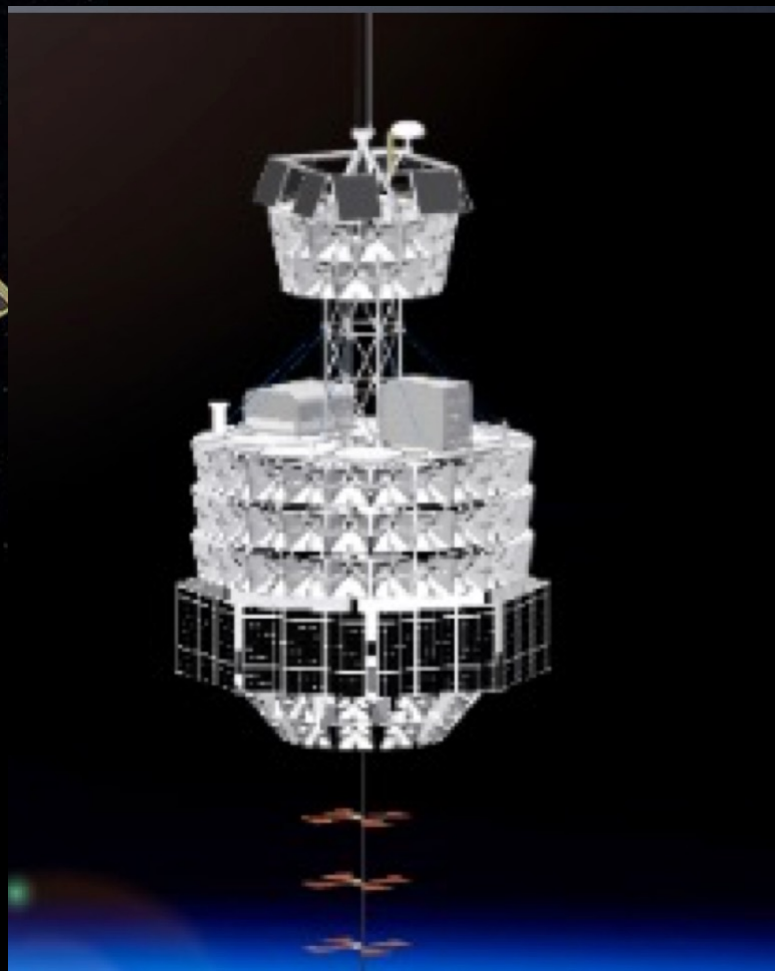
CASE/ARIEL (2029)



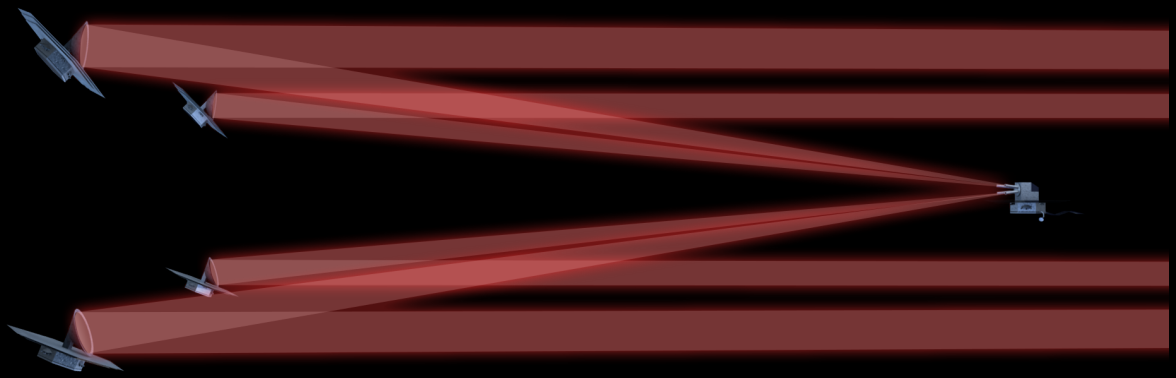
UVEX (2030)

THE WEE ONES



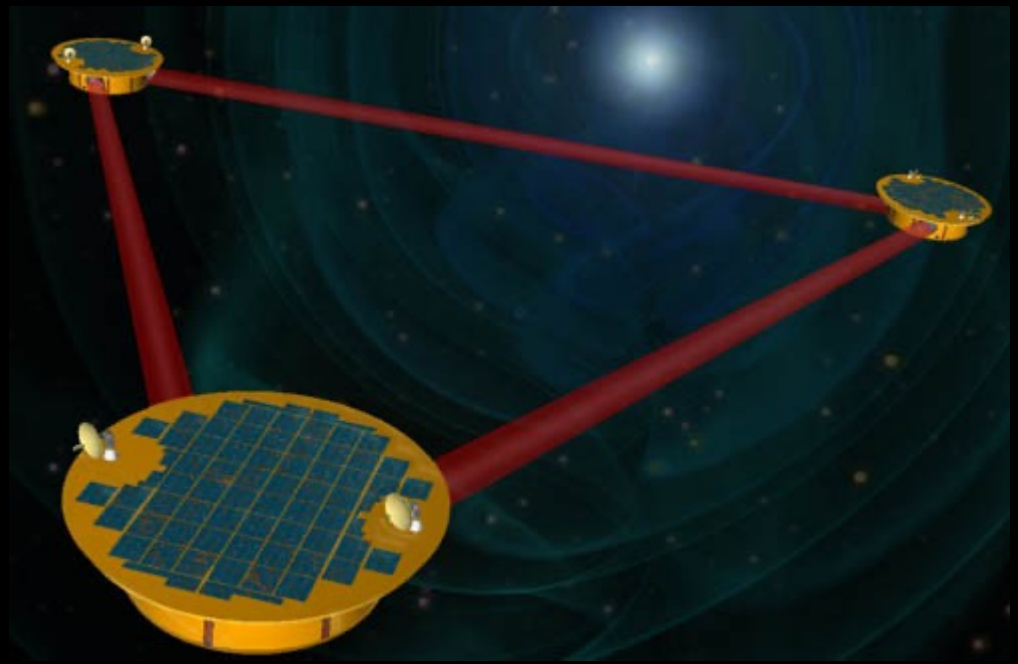


FORMATION FLYING



LIFE

LISA



RISK VS IMPATIENCE

- The key science questions of the next decade and beyond are well defined
- Many of missions are not
- We are often forced to pit risk vs impatience
- A different paradigm to technology maturation and risk reduction is needed

A ship is safe in harbor, but that’s not what ships are for

JOHN SHEDD

THE FAR FUTURE

	Formative Era					Visionary Era			
	GW Surveyor	CMB-pol Surveyor	FIR Surveyor	LUVOIR Surveyor	X-ray Surveyor	GW Mapper	Cosmic Dawn Mapper	ExoEarth Mapper	Black Hole Mapper
Demographics of planetary systems			■	■				■	
Characterizing other worlds			■	■				■	
Our nearest neighbors and the search for life				■				■	
The origins of stars and planets			■	■				■	
The Milky Way and its neighbors	■	■	■	■	■	■		■	■
The history of galaxies	■		■	■	■	■	■	■	■
The origin and fate of the universe	■	■		■	■	■	■		
Extremes of matter and energy	■	■			■	■			■
Ripples of space-time	■	■				■			

■ Primary Goals ■ Secondary Goals

COMING FULL CIRCLE