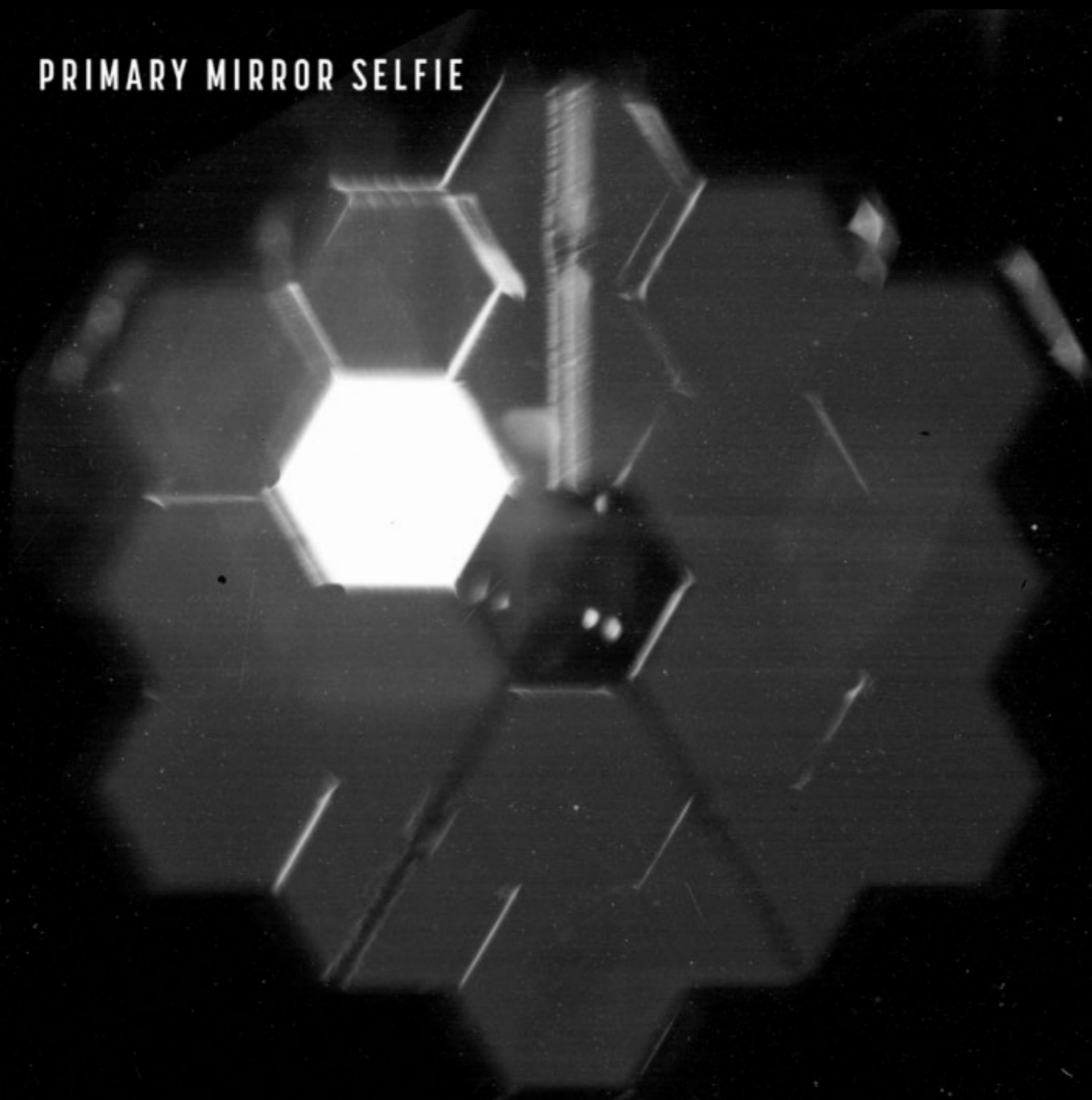


JOHN O'MEARA

GAS, GALAXIES, AND
GREAT OBSERVATORIES

TRL-9 NEVER LOOKED BETTER

PRIMARY MIRROR SELFIE



ASTRO2020 FOUNDATIONS

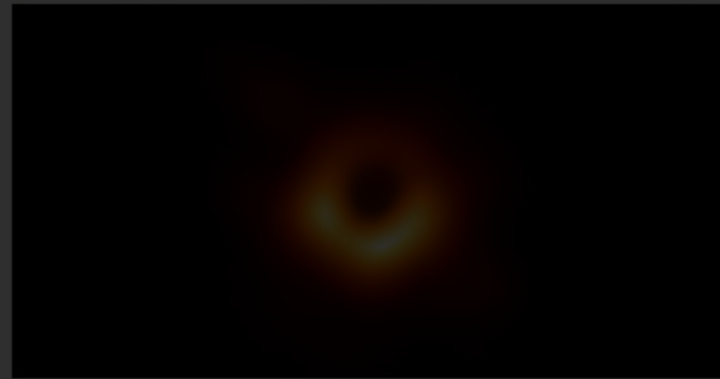


Worlds and Suns in Context

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

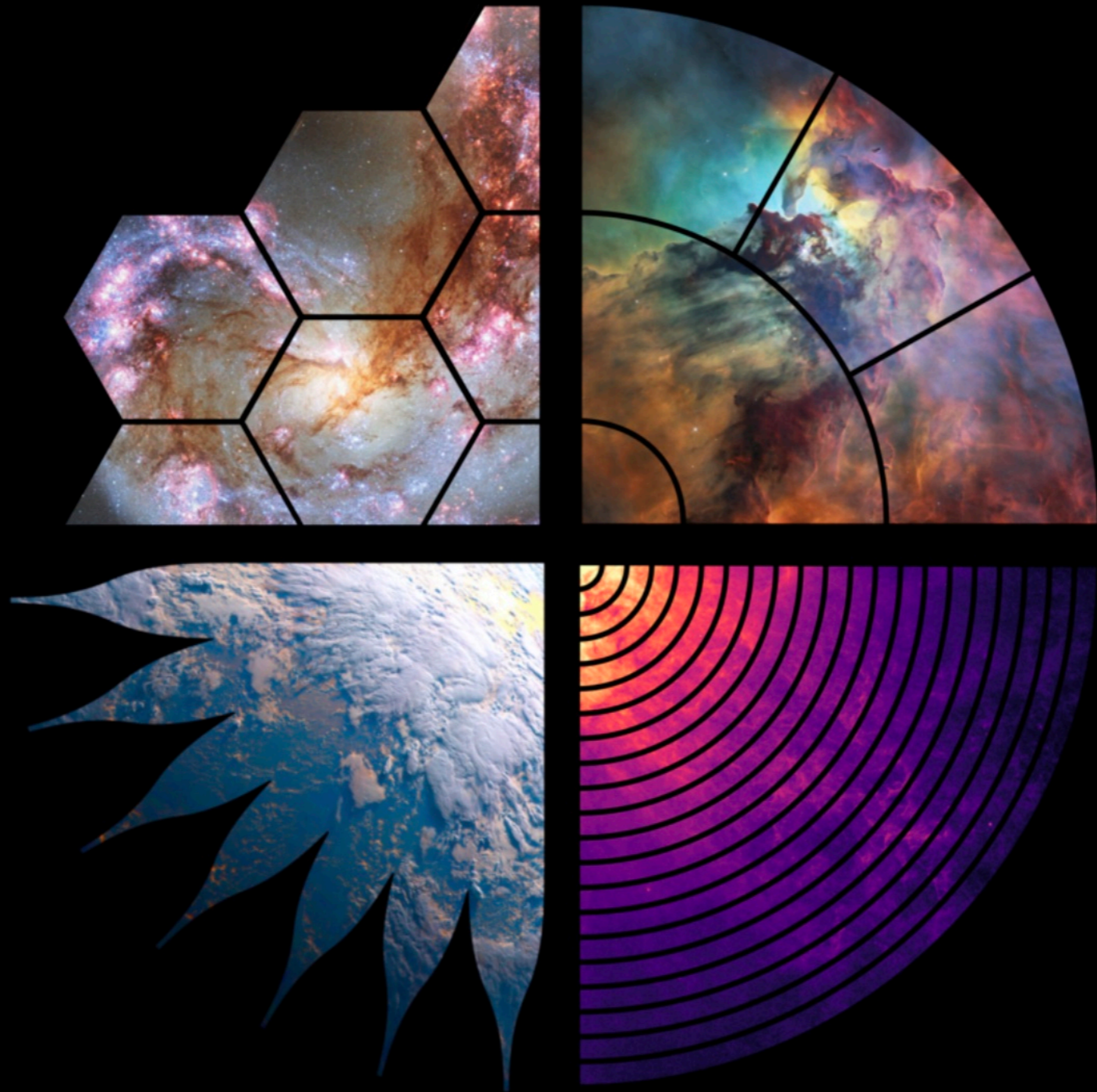
Research in the coming decade will revolutionize our understanding of the origins and evolution of galaxies, from the cosmic webs of gas that feed them to the formation of stars. New observational capabilities across the electromagnetic spectrum along with computation and theory will help resolve the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

KEY RECOMMENDATIONS:



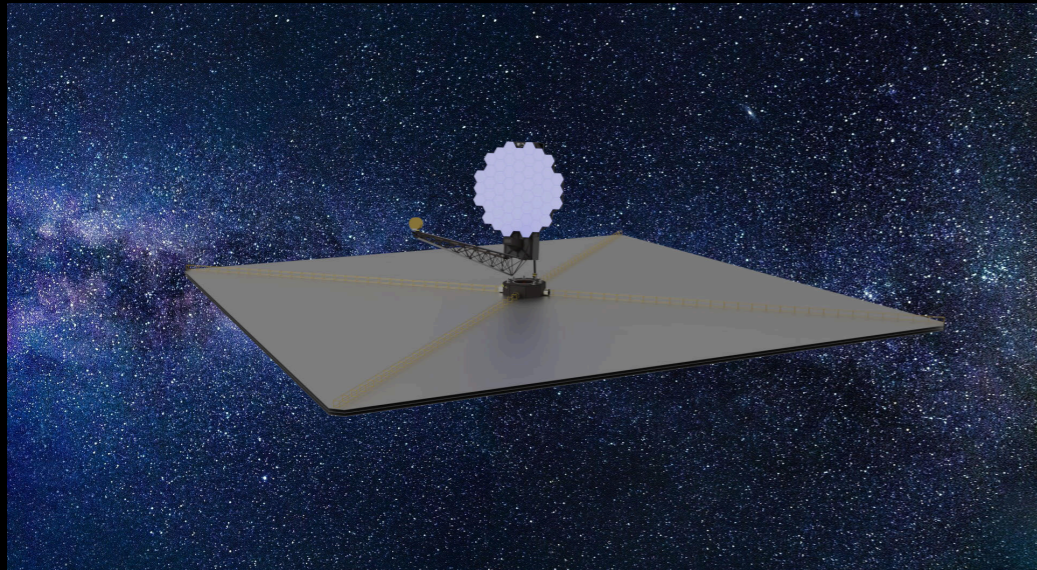
The most effective way to do it, is to do it.

-AMELIA EARHART



R E M A I N I N L I G H T

THE FUTURE GREAT OBSERVATORIES



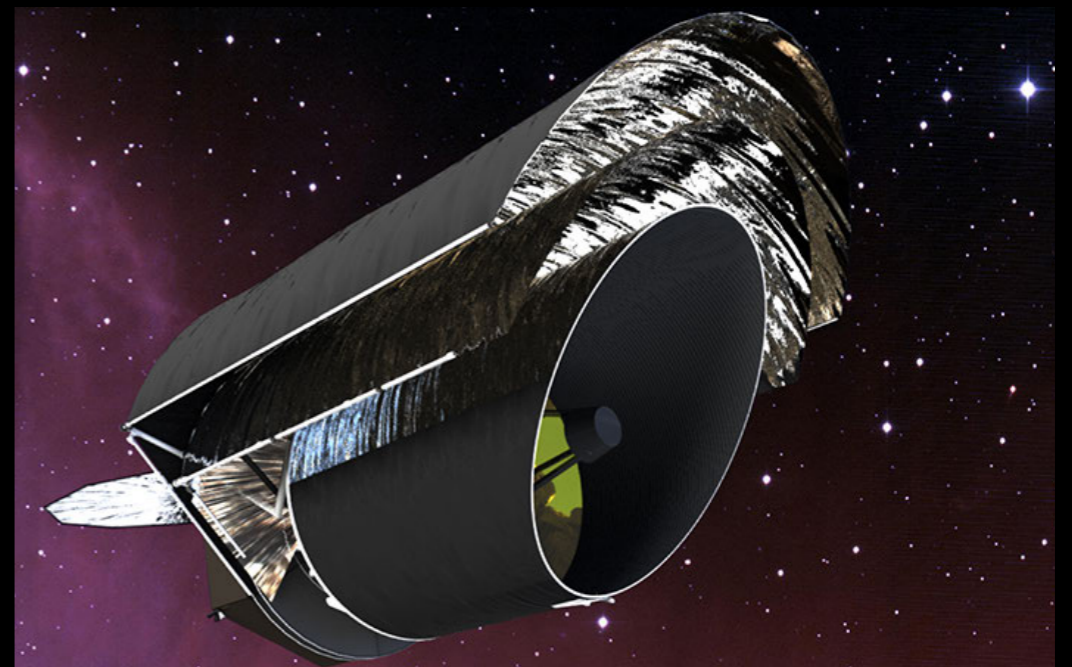
LUVOIR



HABEX

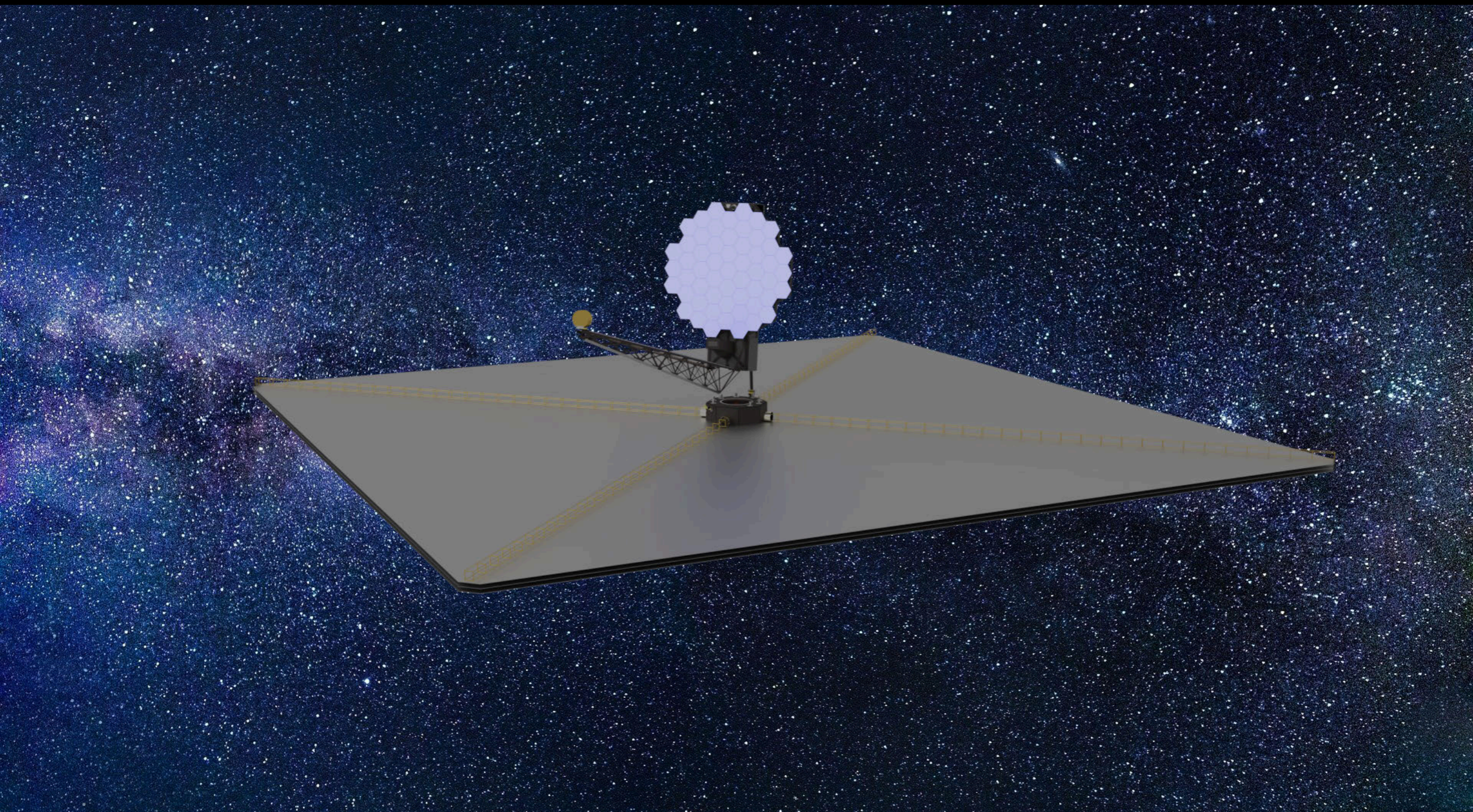


LYNX



ORIGINS

THE FIRST IN THE FLEET



National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-0001



March 11, 2016

Reply to Attn of Director, Astrophysics Division

Dear Dr. John O'Meara,

I am pleased to inform you that you have been appointed to serve as a member of the Science and Technology Definition Team (STDT) for the Large Ultraviolet/Optical/Infrared (LUVOIR) Surveyor Mission Concept Study. NASA greatly values your expertise and time, and appreciates your willingness to participate in the STDT.

Over the coming years you will play a central role in preparing a compelling and executable mission concept for consideration by the 2020 Decadal Survey. The full charter for the STDT is available at the following site:

http://science.nasa.gov/media/medialibrary/2016/01/04/Mission_Concept_Study_and_Definition_Team_Charter-V1_2015-12-28.pdf

Your term of service begins with immediate effect and completes when all input to the 2020 Decadal Survey has been provided. You should soon expect an email from the Community Chairs of the STDT with more information about the study.

We look forward to assisting you and the rest of the STDT in developing this exciting mission concept.

Sincerely,

A handwritten signature in black ink, appearing to read "PH", written over a light blue horizontal line.

Paul Hertz
Director, Astrophysics Division

How it started

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-0001



March 11, 2016

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Sincerely,

Paul Hertz
Director, Astrophysics Division

Ecosystems, will link observations and modeling of the stars, galaxies, and the gas and energetic processes that couple their formation, evolution, and destinies.

Within each of these broad and rich scientific themes, three priority areas motivate recommended investments over the coming decade. "Pathways to Habitable Worlds" is a step-by-step program to identify and characterize Earth-like extrasolar planets, with the ultimate goal of obtaining imaging and spectroscopy of potentially habitable worlds. "New Windows on the Dynamic Universe" is aimed at combining time-resolved multi-wavelength electromagnetic observations from space and the ground with non-electromagnetic signals to probe the nature of black holes, neutron stars, the explosive events and mergers that give rise to them, and to use signatures imprinted by gravitational waves to understand what happened in the earliest moments in the birth of the universe. "Unveiling the Drivers of Galaxy Growth" is aimed at revolutionizing our understanding of the origins and evolution of galaxies, from the nature of the tenuous cosmic webs of gas that feed them, to the nature of how this gas condenses and drives the formation of stars.

THE RECOMMENDED PROGRAM

Major leaps in observational capabilities will be realized in the coming decade when new large telescopes and missions commence science operations (Table 7.1). Recommended by previous surveys, with some undertaken with international partners, these projects and programs are an essential base upon which the survey's scientific vision is built. It is essential that these initiatives be completed, and the scientific programs be supported at levels that ensure full exploitation of their potential by the U.S. scientific community.

Going forward, this survey lays out a strategy for federal investments aimed at paving a pathway from the foundations of the profession to the bold scientific frontiers.

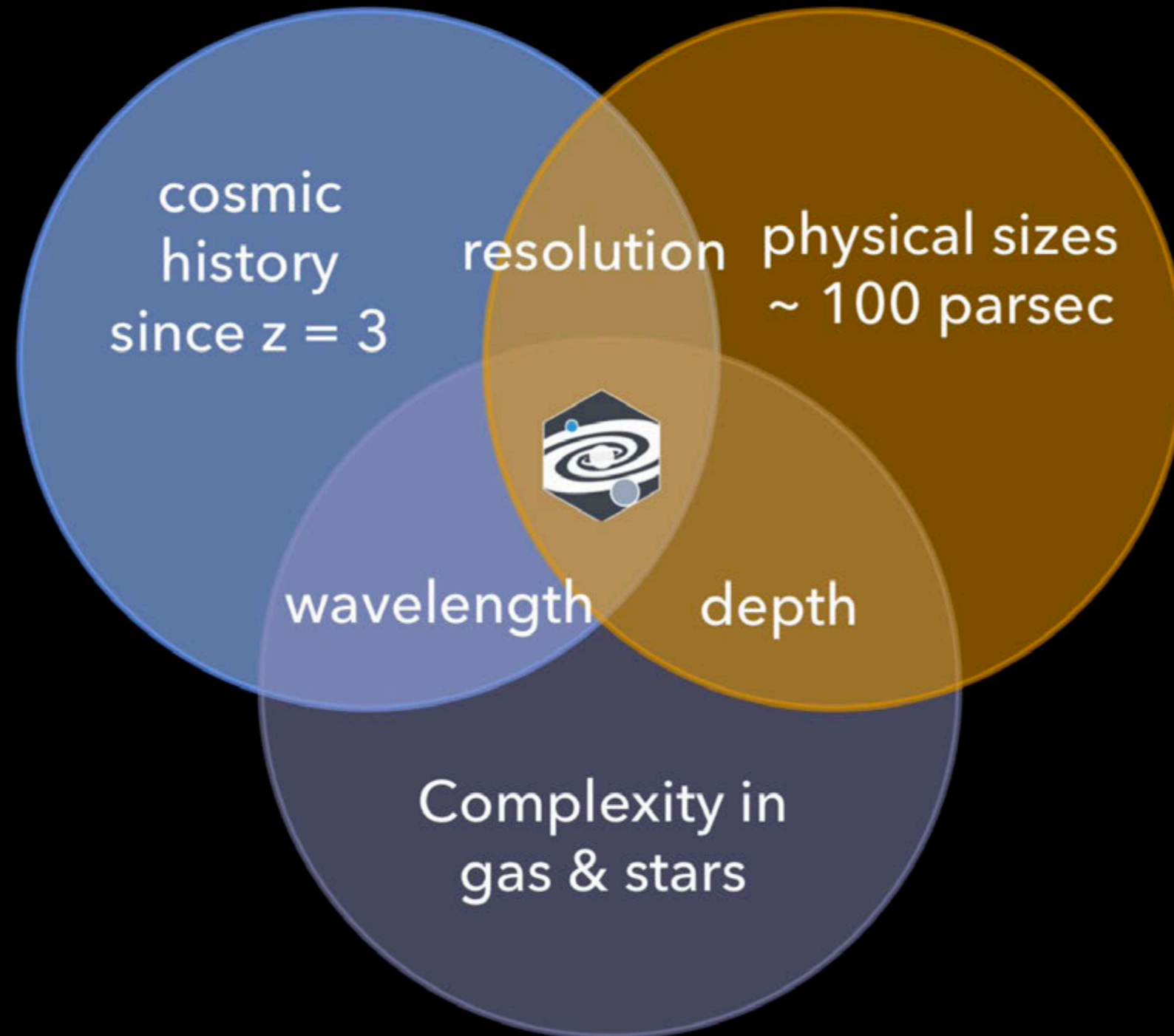
Large Programs that Forge the Frontiers

These scientific visions—Pathways to Habitable Worlds, New Windows on the Dynamic Universe, and Unveiling the Drivers of Galaxy Growth—require the major recommended investments in large projects to begin design and construction in the coming 10 years (Tables S.5 and S.6; Figure S.1).³ In space, achieving the community's most ambitious and visionary ideas in a sustainable way, and realizing the broad capabilities demanded by the richness of the science, requires a re-imagining of the ways in which large missions are planned, developed, and implemented. The **Great Observatories Mission and Technology Maturation Program** (Table S.5) would provide significant early investments in the co-maturation of mission concepts and technologies, with appropriate decadal survey input on scope, and with checks and course corrections along the way. Inspired by the vision of searching for signatures of life on planets outside of the solar system, and by the transformative capability such a telescope would have for a wide range of astrophysics, the survey recommends that the first mission to enter this program is a **large (~6 m aperture) infrared/optical/ultraviolet (IR/O/UV) space telescope**. The scientific goals of this mission, when achieved, have the potential to profoundly change the way that human beings view our place in the universe. With sufficient ambition, we are poised scientifically and technically to make this transformational step. This endeavor represents a quest that is on the technical forefront, is of an ambitious scale that only NASA can undertake, and it is one where the United States is uniquely situated to lead the world. If maturation proceeds as expected, the survey recommends that formulation and implementation begin by the end of the 2020 decade. To prepare for future large, strategic missions, 5 years after beginning the maturation program for the IR/O/UV mission, the survey

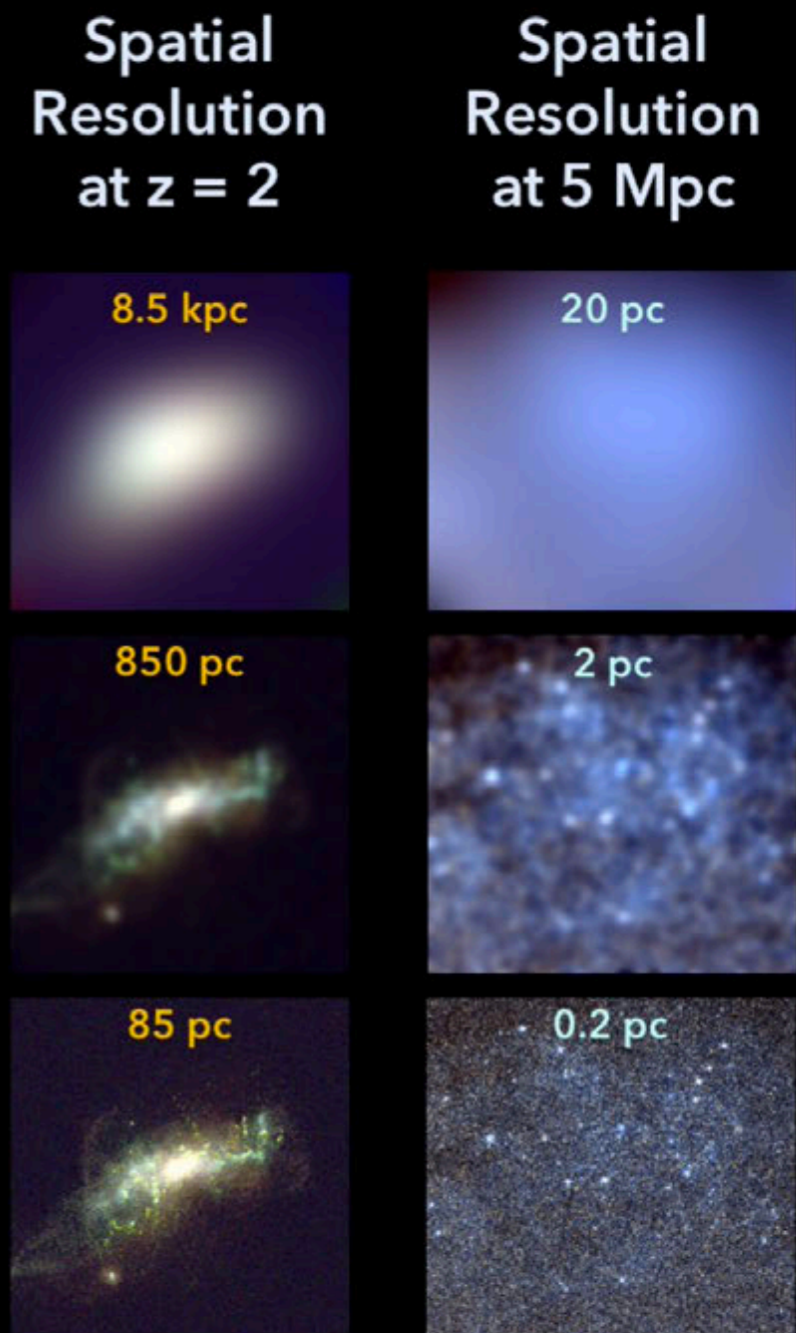
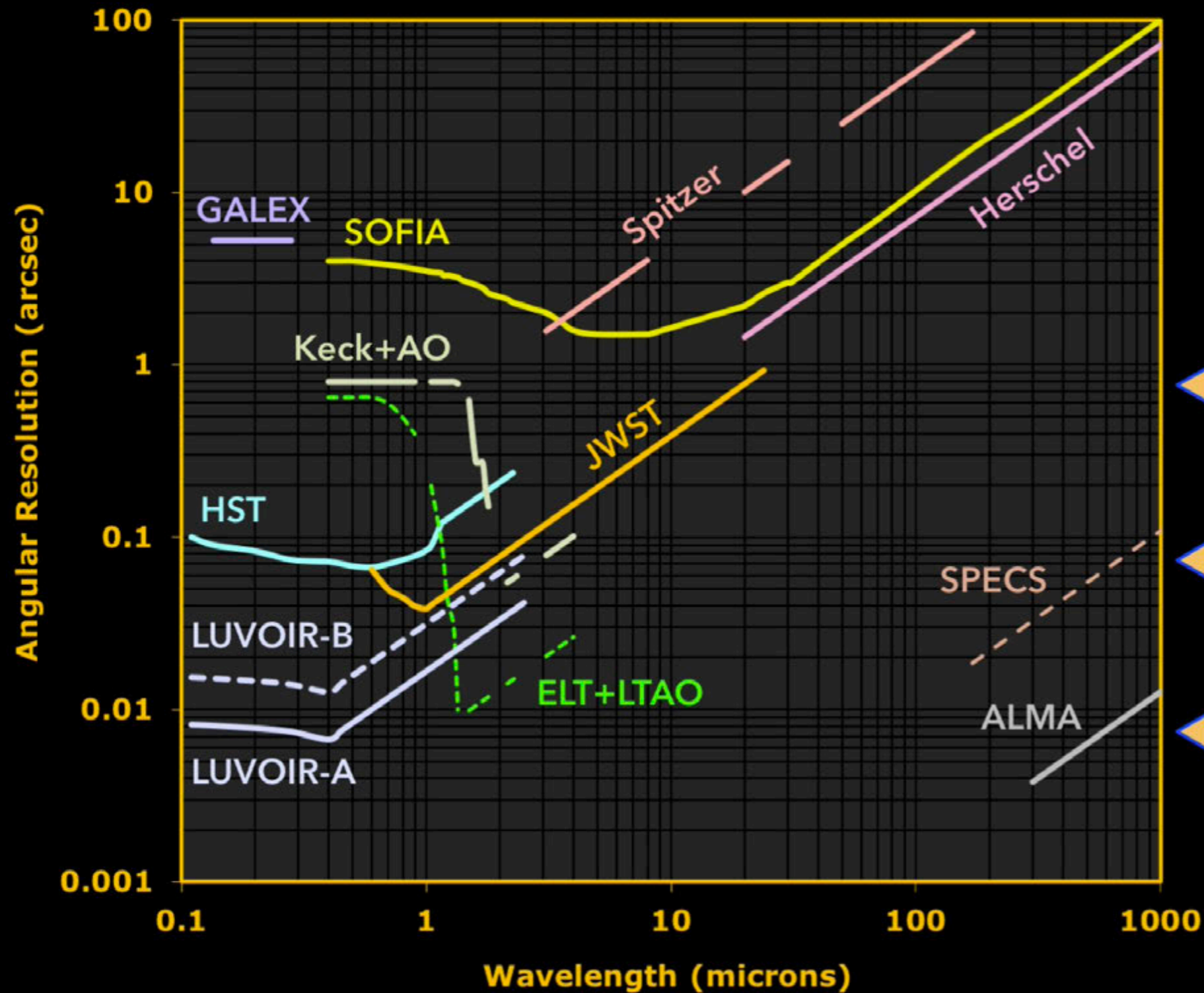
³ For space, large projects are defined as those with costs exceeding \$1.5 billion. For ground-based initiatives, large projects are defined as those exceeding \$130 million for the total program investment.

How it's going

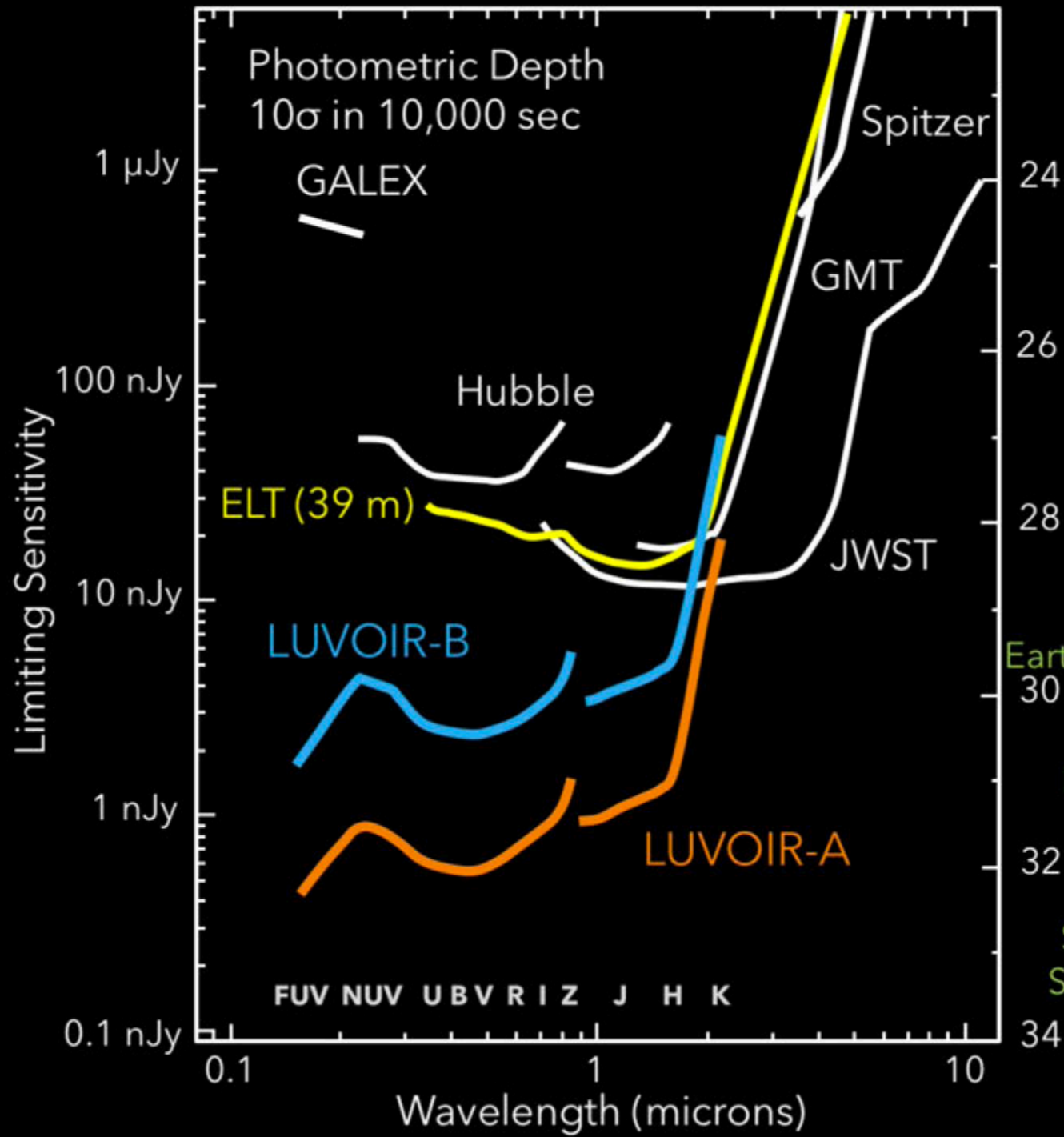
THE ESSENTIALS – RESOLUTION, DEPTH, AND WAVELENGTH



THE ESSENTIAL RESOLUTION



THE ESSENTIAL DEPTH

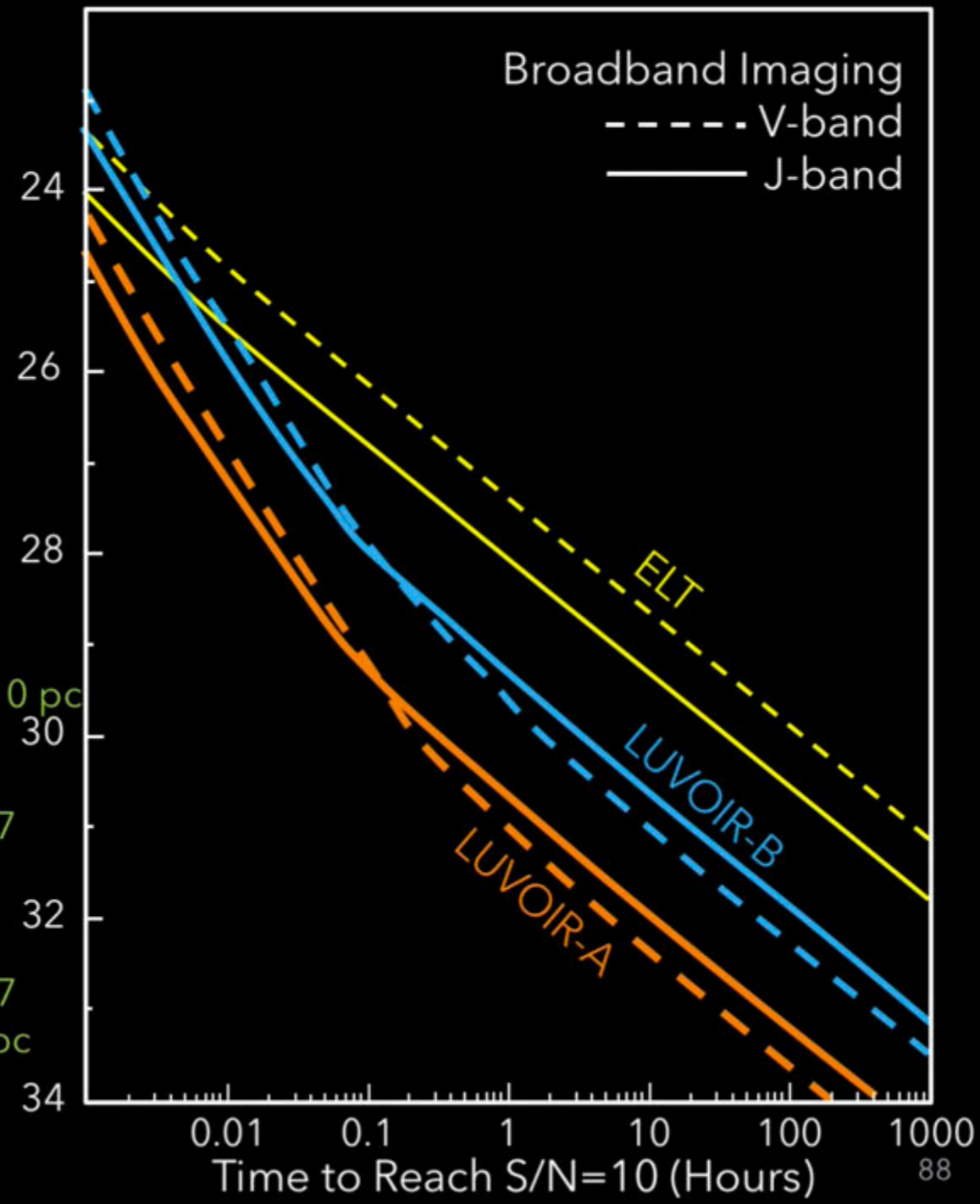


Limiting AB magnitude

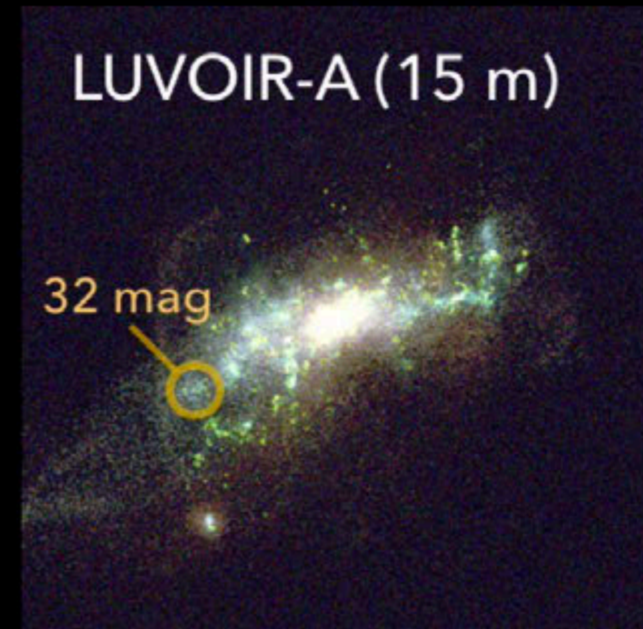
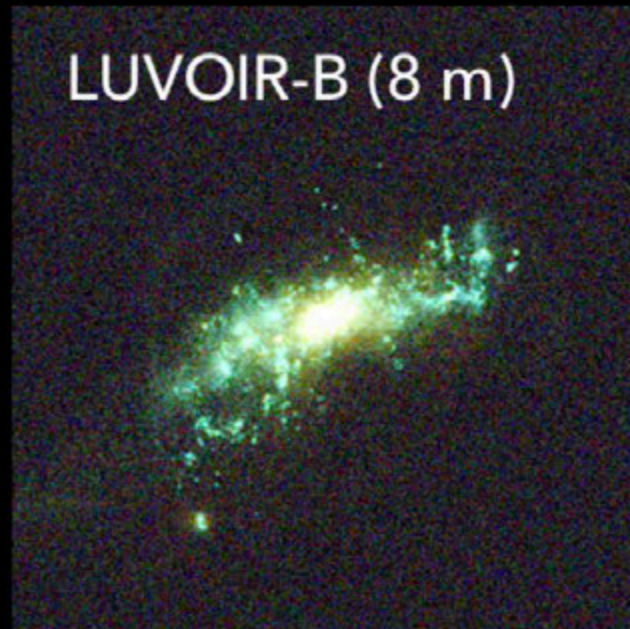
Earth twin at 10 pc
30

LMC at z=7
32

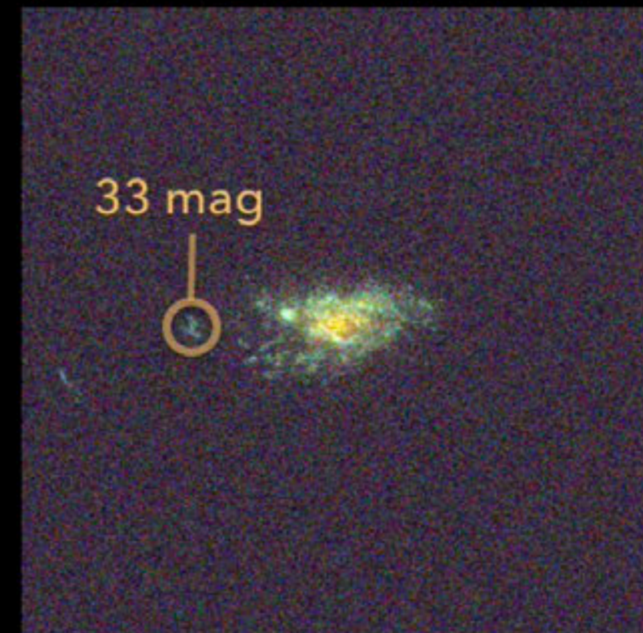
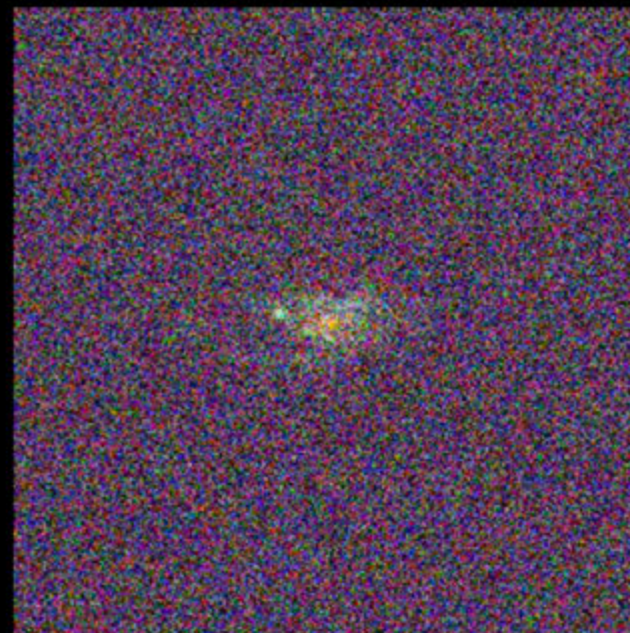
SMC at z=7
Sun at 5 Mpc
34



SEEKING THE BUILDING BLOCKS OF GALAXIES

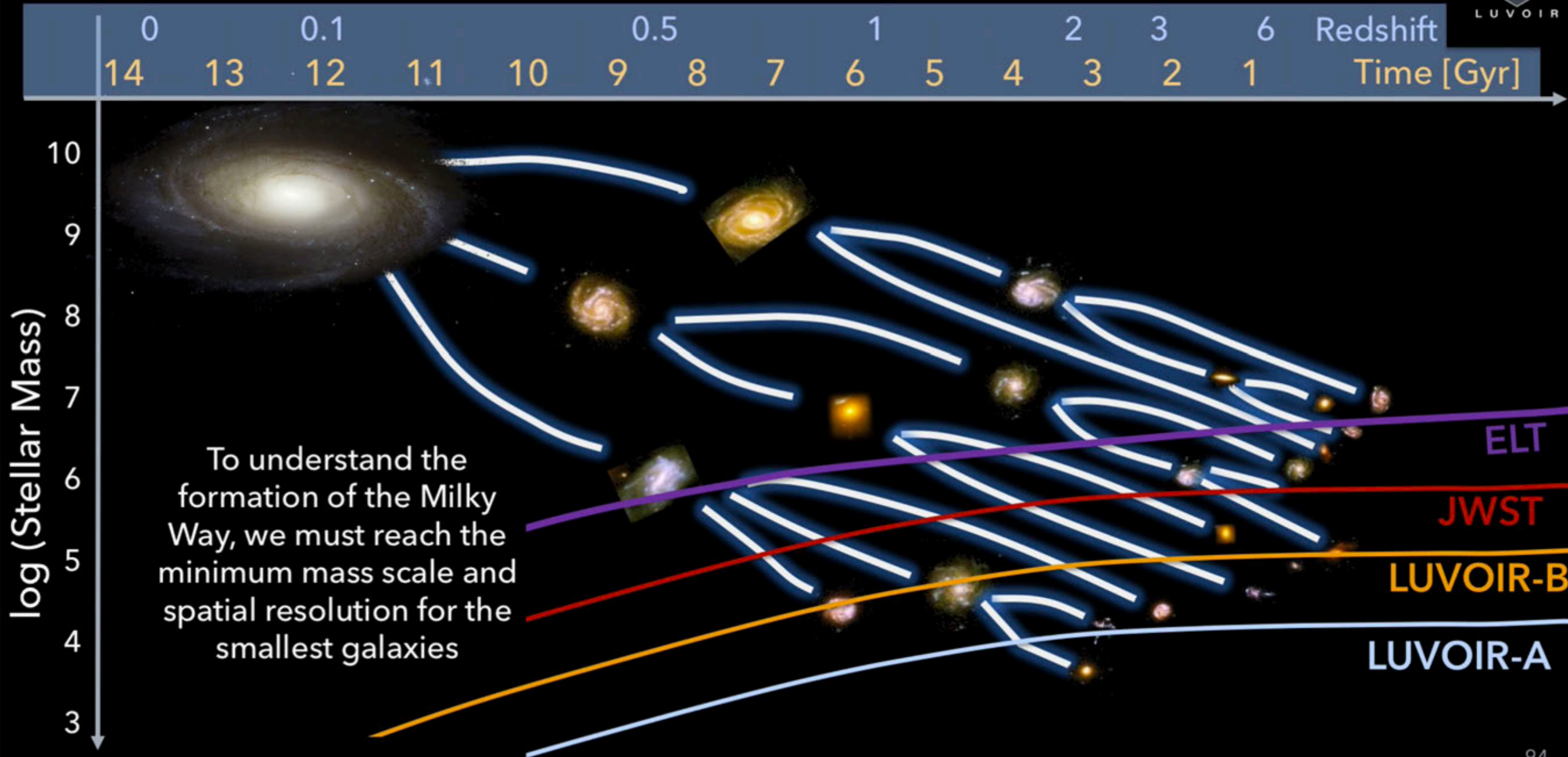


$z = 2$ galaxy, 10^9 solar masses ($m_{AB} \sim 25.5$)

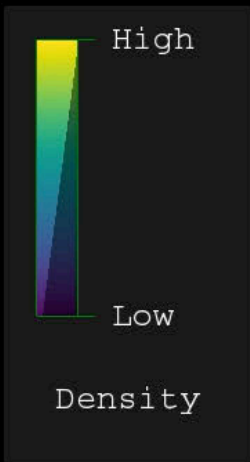


$z = 2$ galaxy, 10^6 solar masses ($m_{AB} \sim 30$)

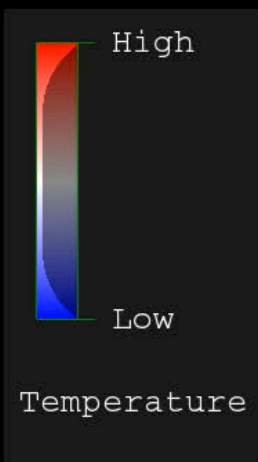
THE COSMIC LANDSCAPE - MILKY WAY ASSEMBLY



FOLLOW THE GAS

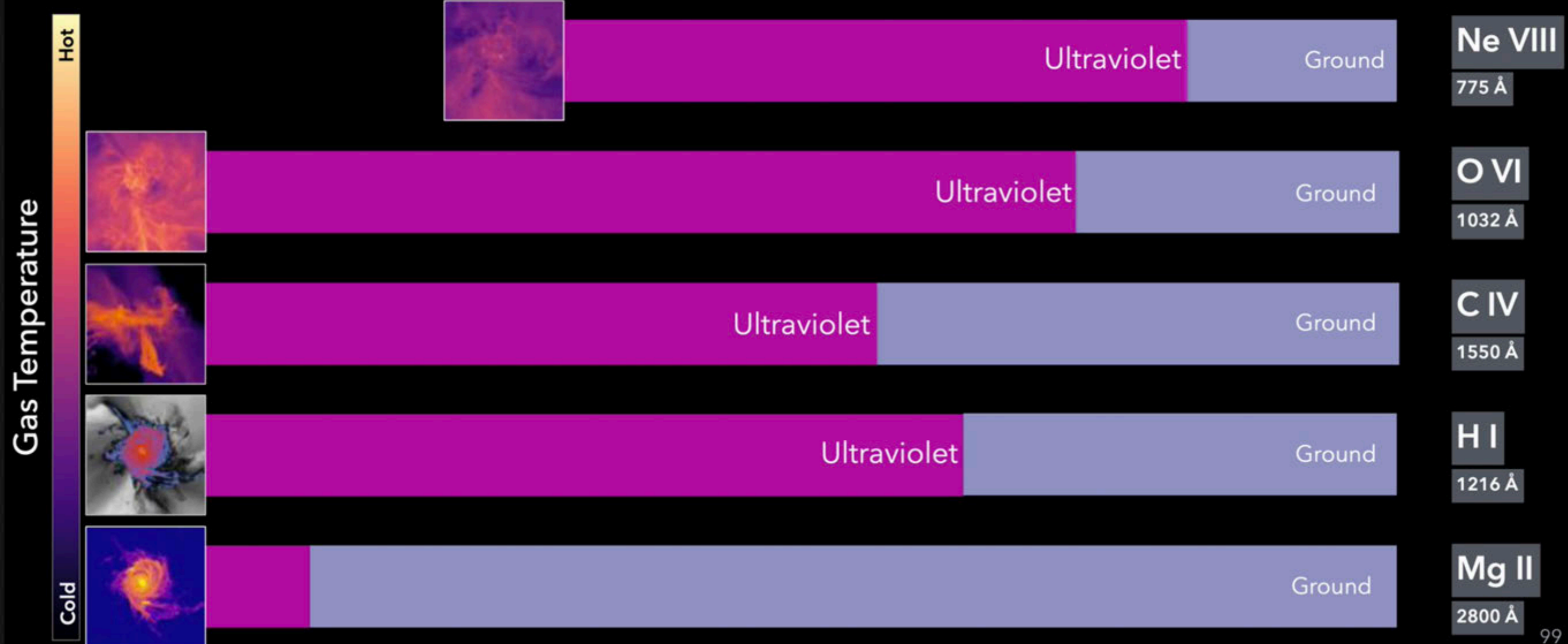


$t = 1.0 \text{ Gyr}$
 $z = 5.65$

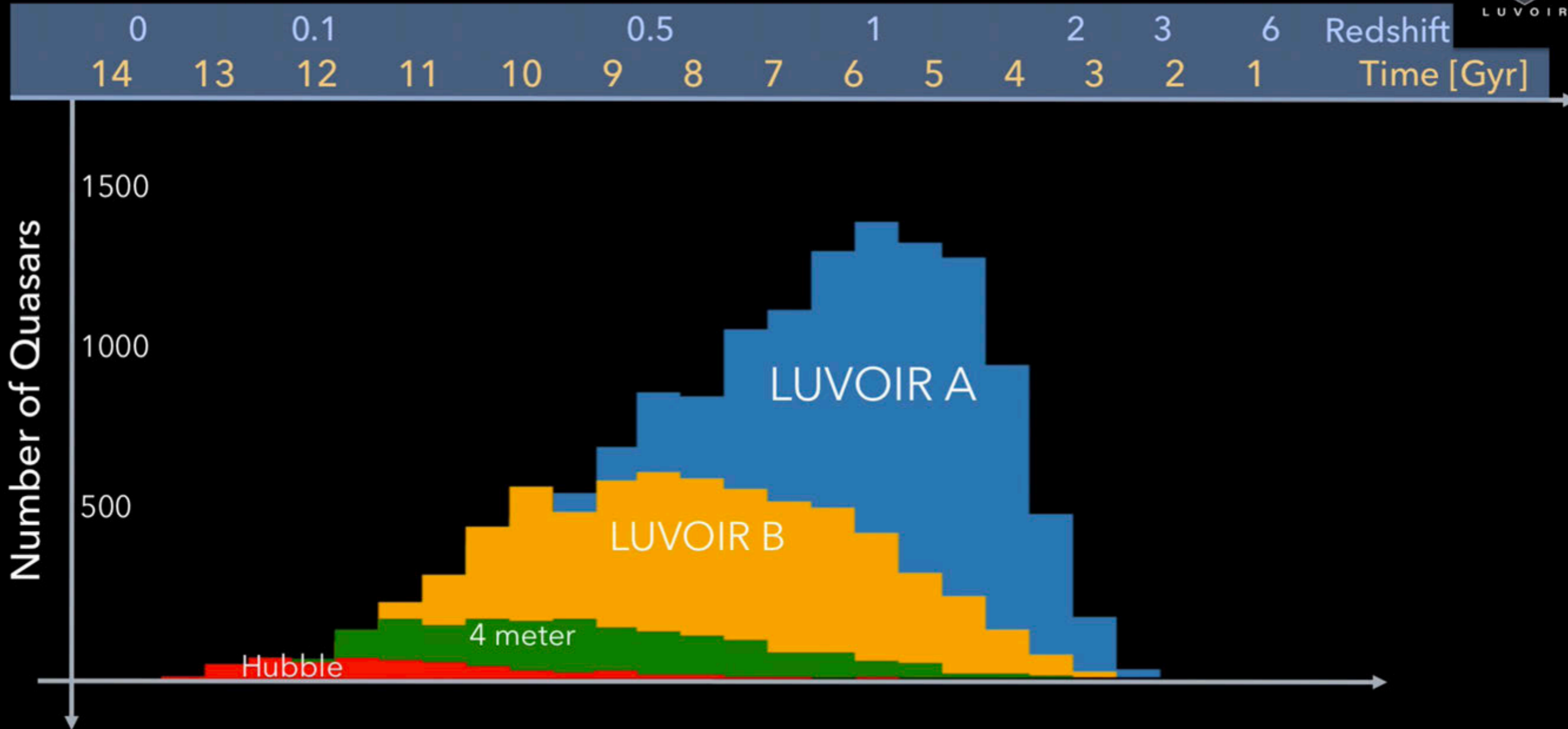


Simulation courtesy the FOGGIE team

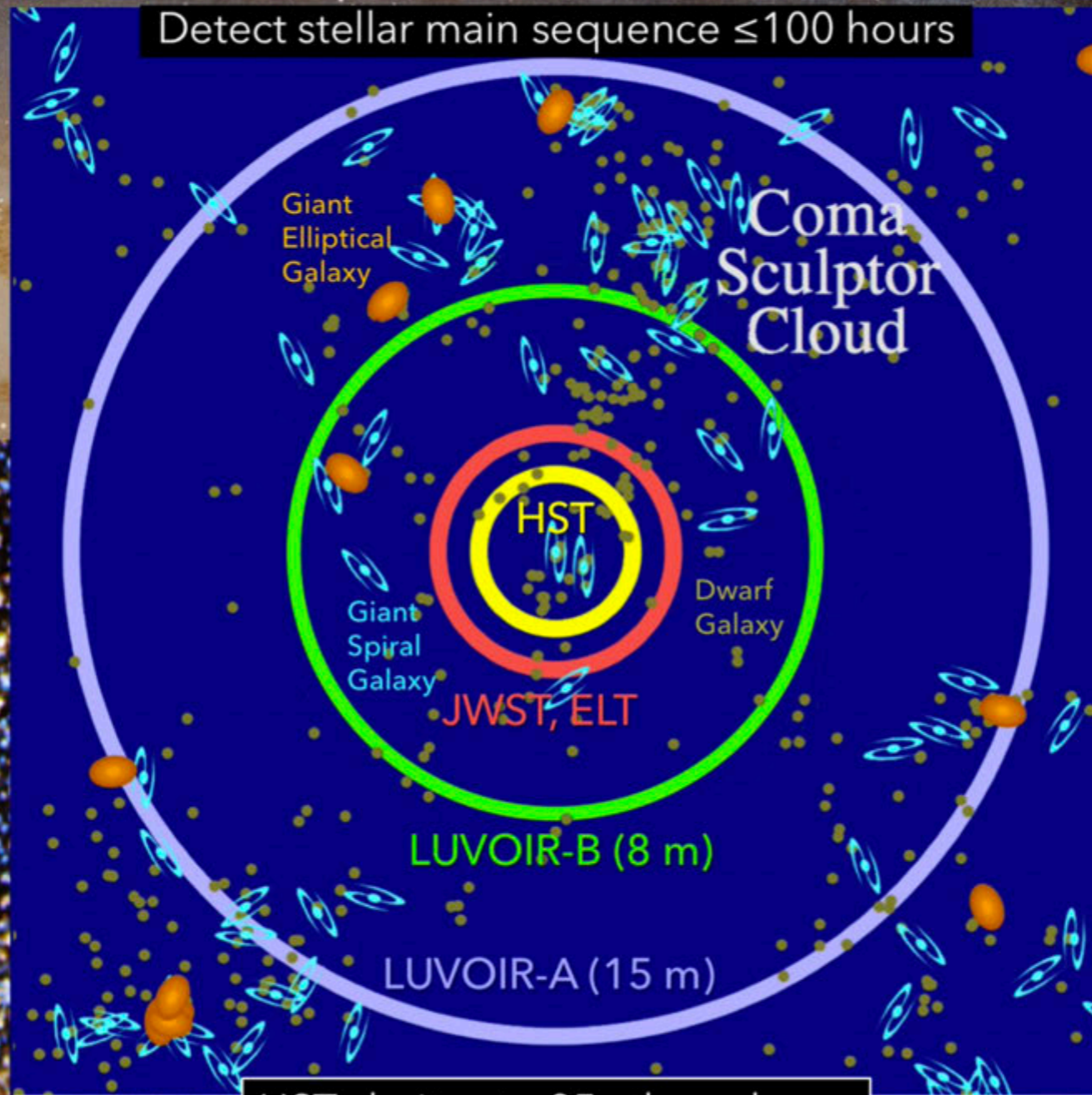
THE BARYON CYCLE AND THE ESSENTIAL ULTRAVIOLET



THE BARYON CYCLE AND THE ESSENTIAL ULTRAVIOLET



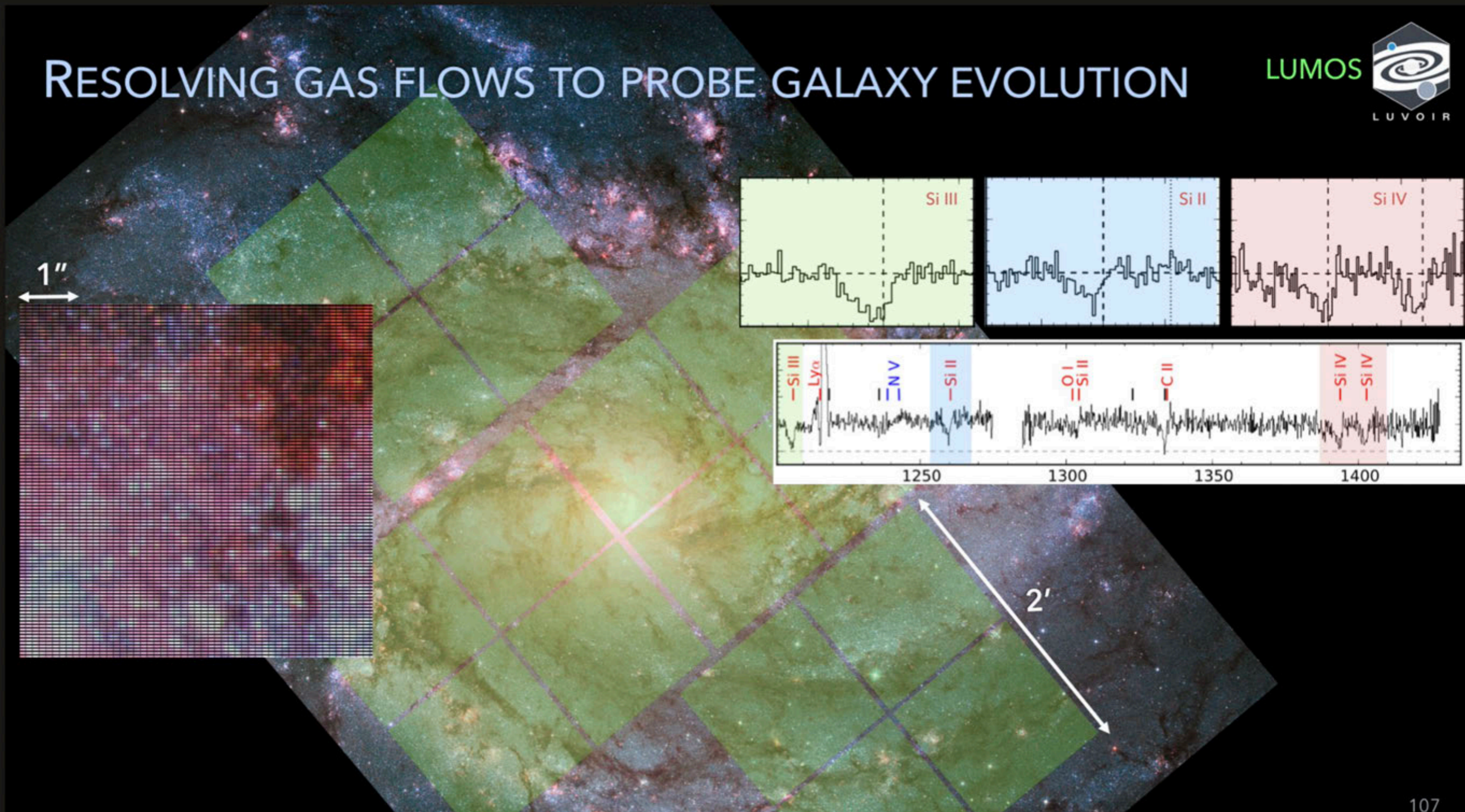
THE HISTORY OF A GALAXY IN ITS STELLAR POPULATIONS



LUVOIR-A

HST clarity at $>35x$ the volume

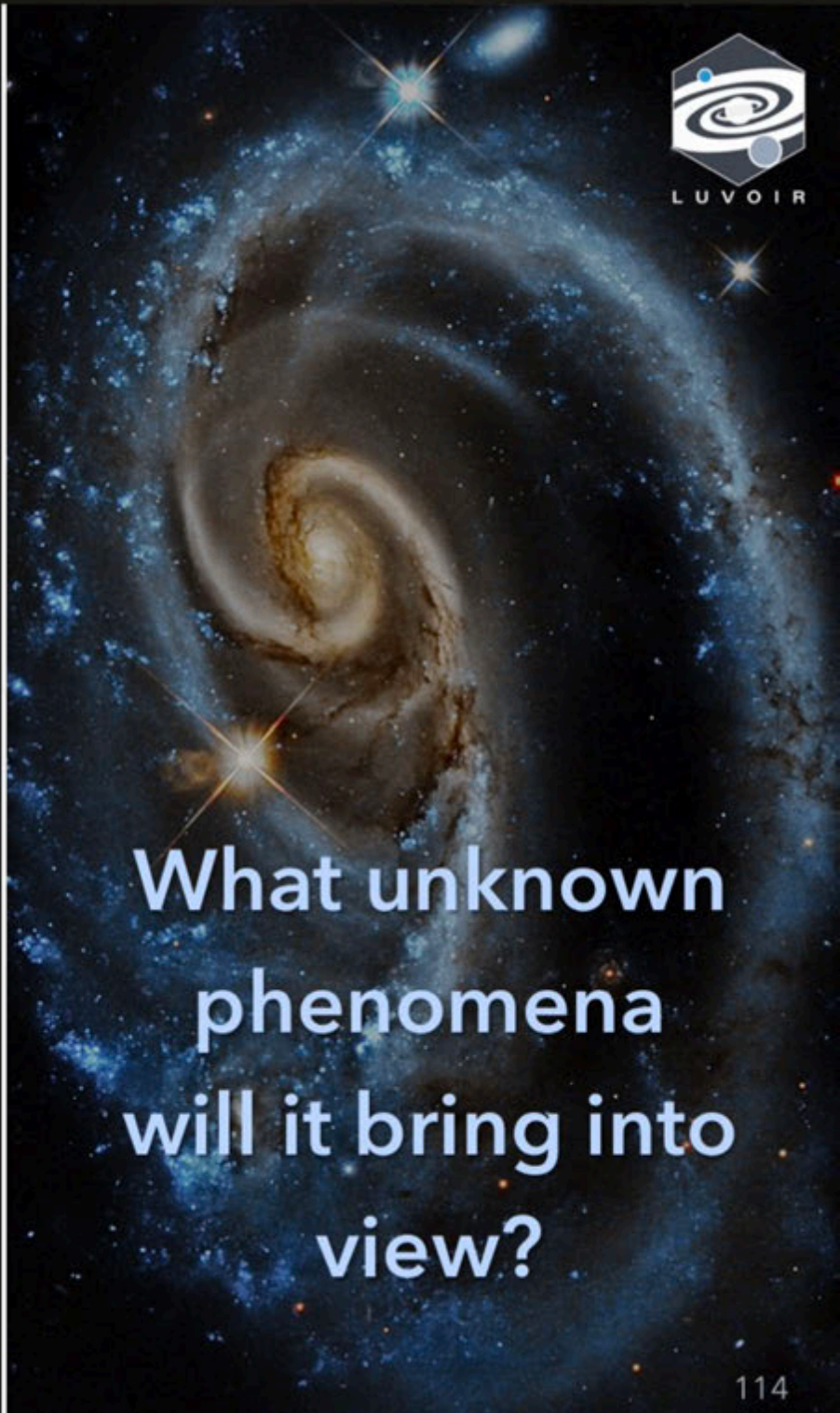
RESOLVING GAS FLOWS TO PROBE GALAXY EVOLUTION



NEW DISCOVERY SPACES

LUVOIR opens new avenues for discovery and serendipity. LUVOIR will ...

- Reach 4-5 mag (40 - 100x) deeper than Hubble and 2-3 mag (6 - 16x) deeper than Webb or the ELTs
- Resolve 100 pc scales at any cosmic time
- Collect UV spectra >1000 times faster than Hubble
- Provide an ultra-stable imaging platform capable of micro-arcsecond astrometry



**What unknown
phenomena
will it bring into
view?**

By failing to prepare, you are preparing to fail


BENJAMIN FRANKLIN

WHAT WE NEED. A VERY INCOMPLETE LIST*

- Simulations
- Catalogs
- Other Catalogs
- Tool Belts
- Other Tool Belts
- Resolve

*Not all of these drive architecture trades...or do they?

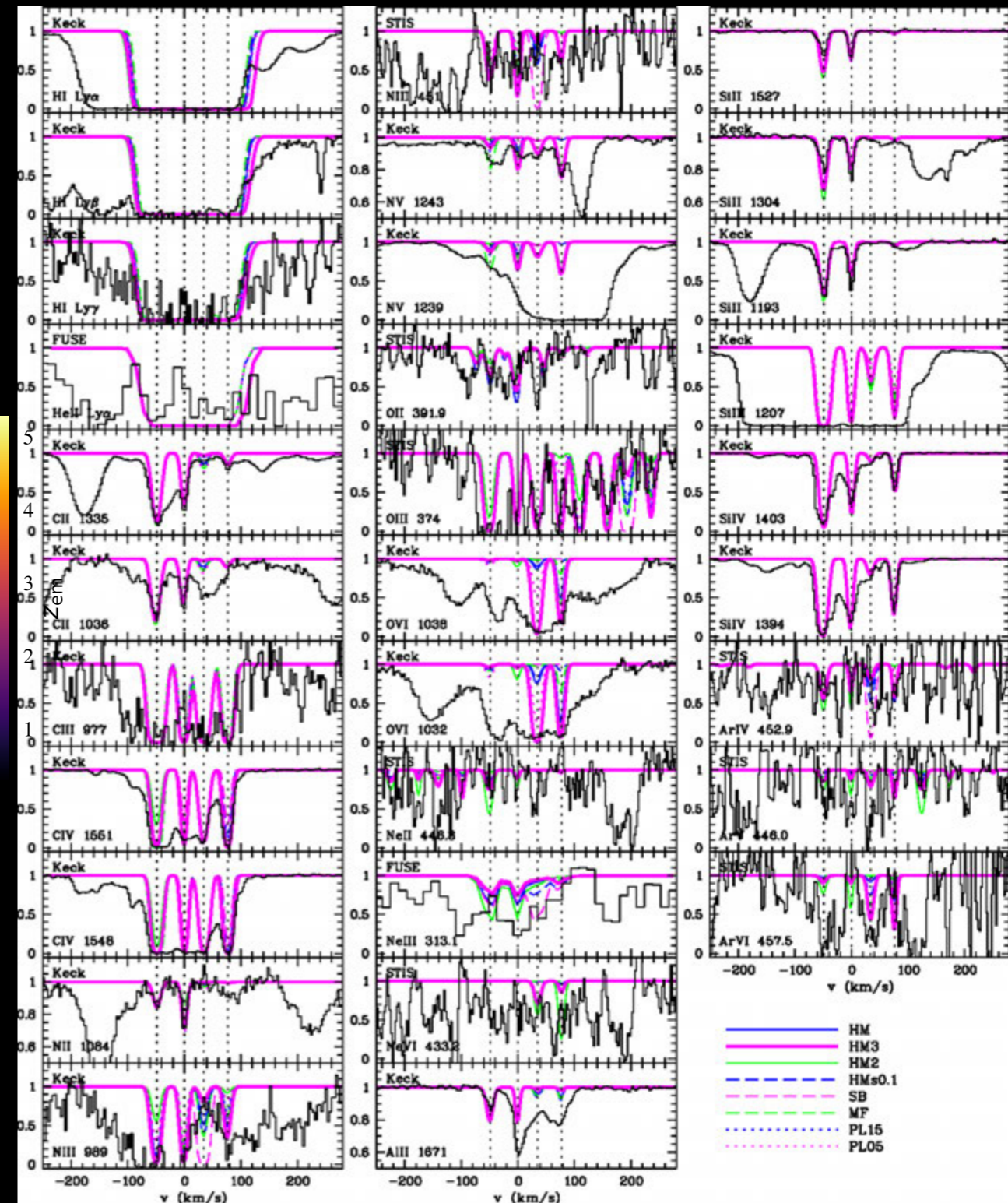
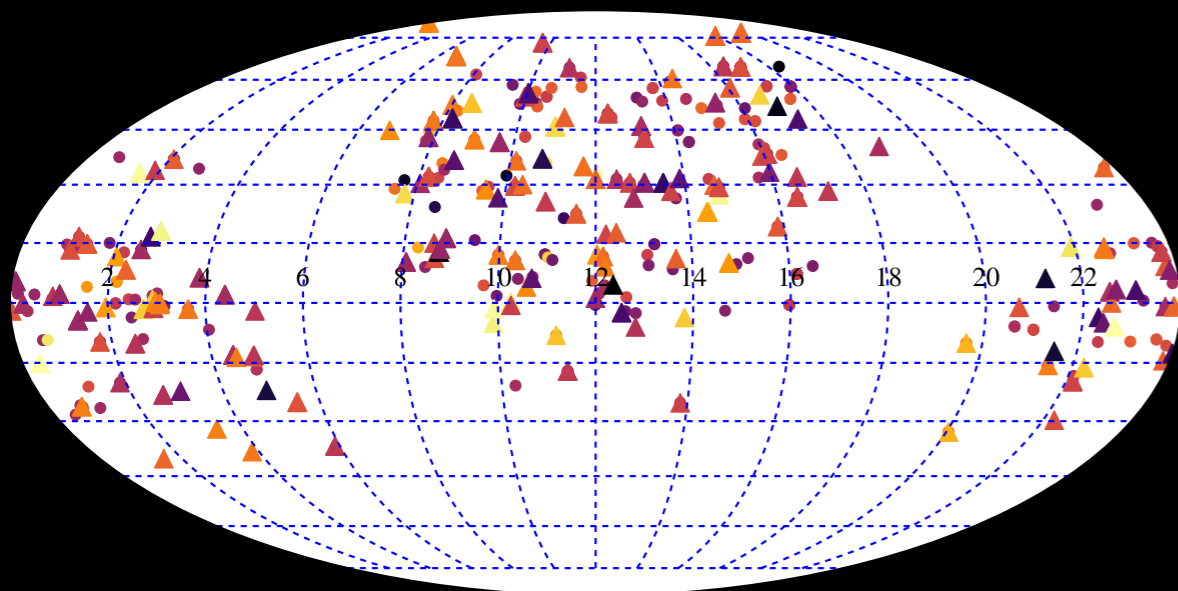
SIMULATIONS

 Galaxy Outflow Snapshot - Density Field
from Evan Schneider

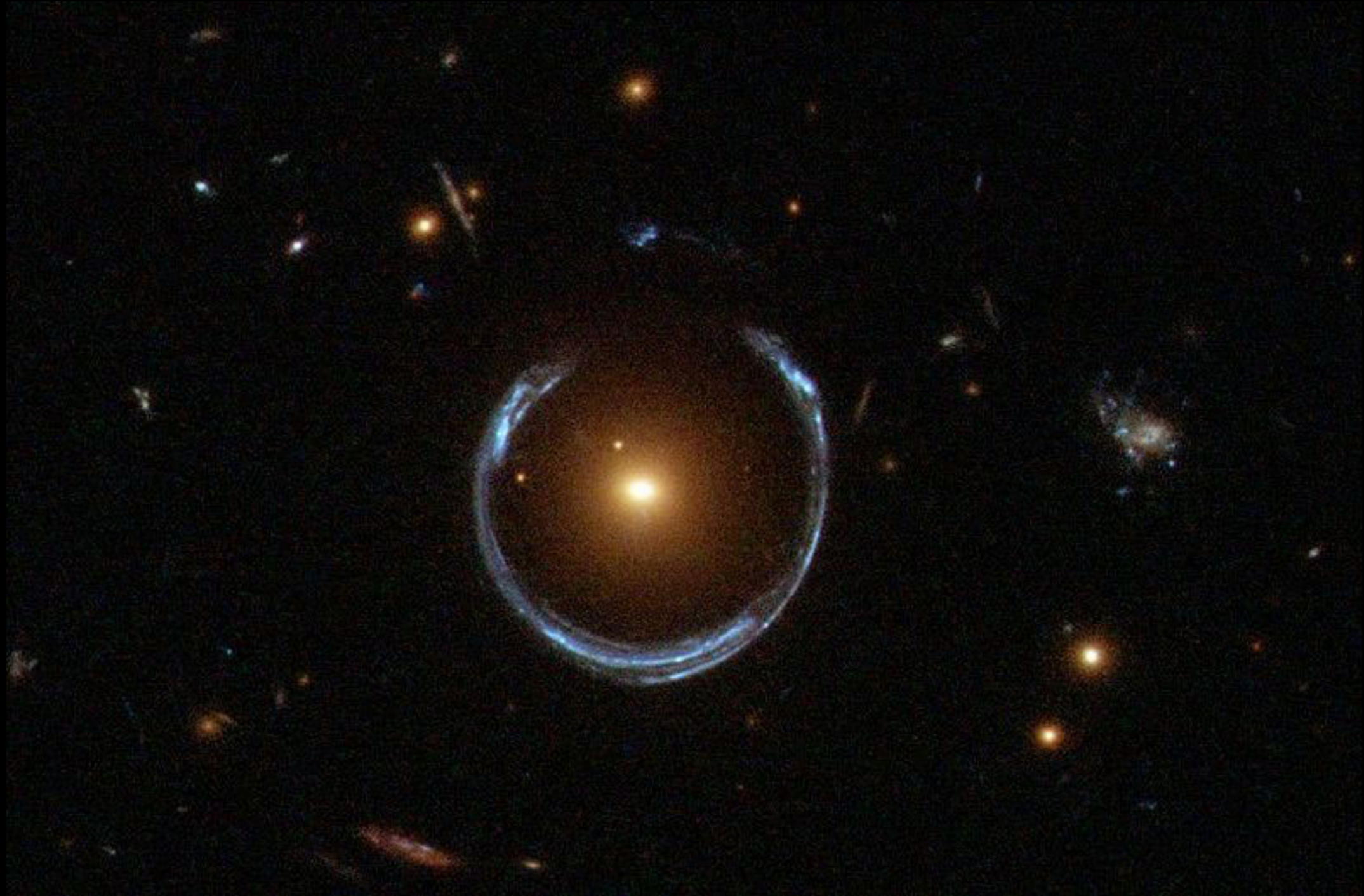


Evan Schneider

CATALOGUES



OTHER CATALOGUES



TOOL BELTS



HDI Photometric ETC

Basic exposure time calculator for optical photometry in multi-band images.



LUMOS Spectroscopic ETC

Simple exposure time calculator for UV spectroscopy.



High-Resolution Imaging Tool

Examples of astronomical objects viewed with different sized telescopes.



ECLIPS Spectroscopic ETC

Simulate UV to NIR reflection spectra of various exoplanets with realistic noise.



Exoplanet Yield Tool

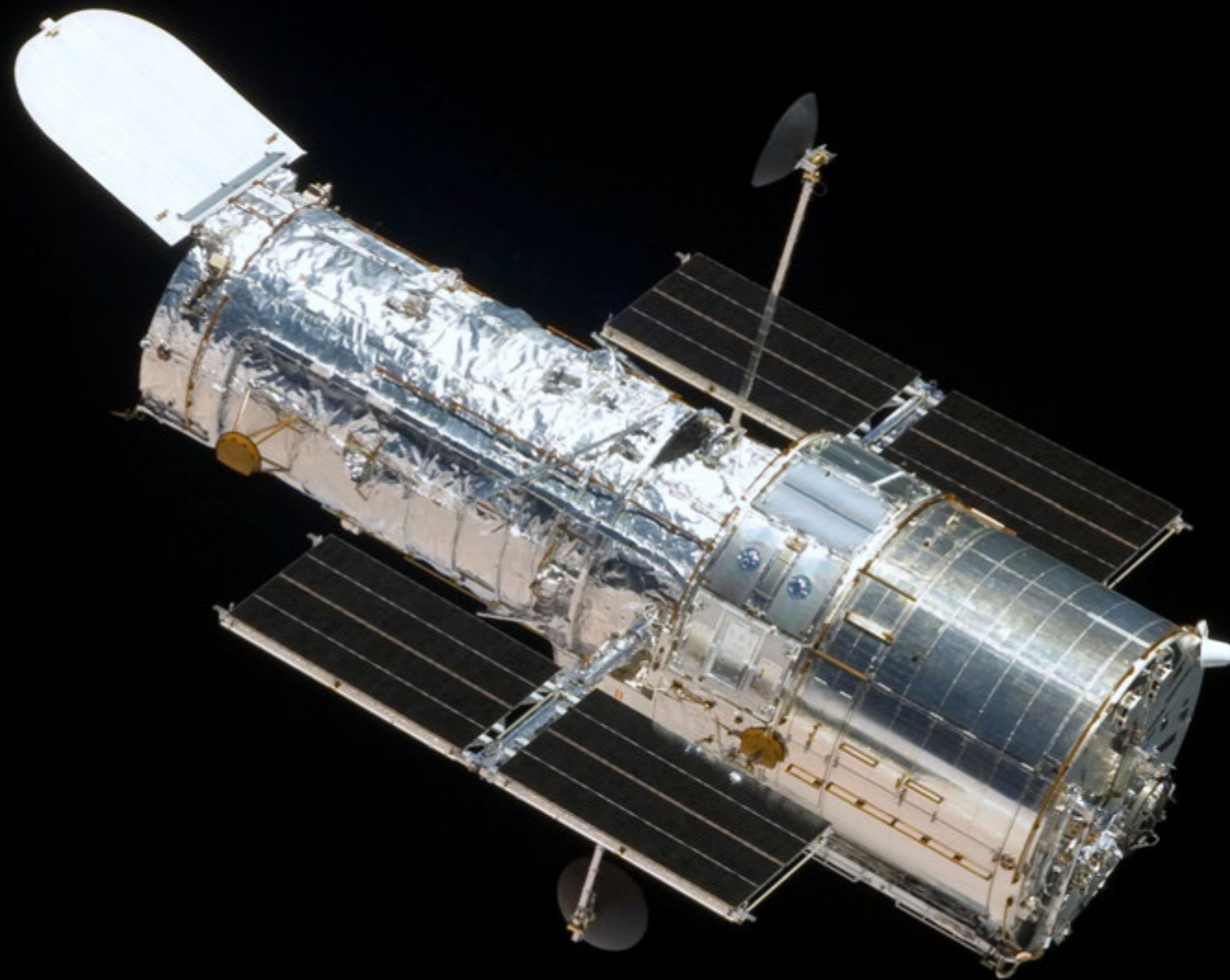
Tool for visualizing yields of observed exoplanets (of various types) as function of basic mission parameters.



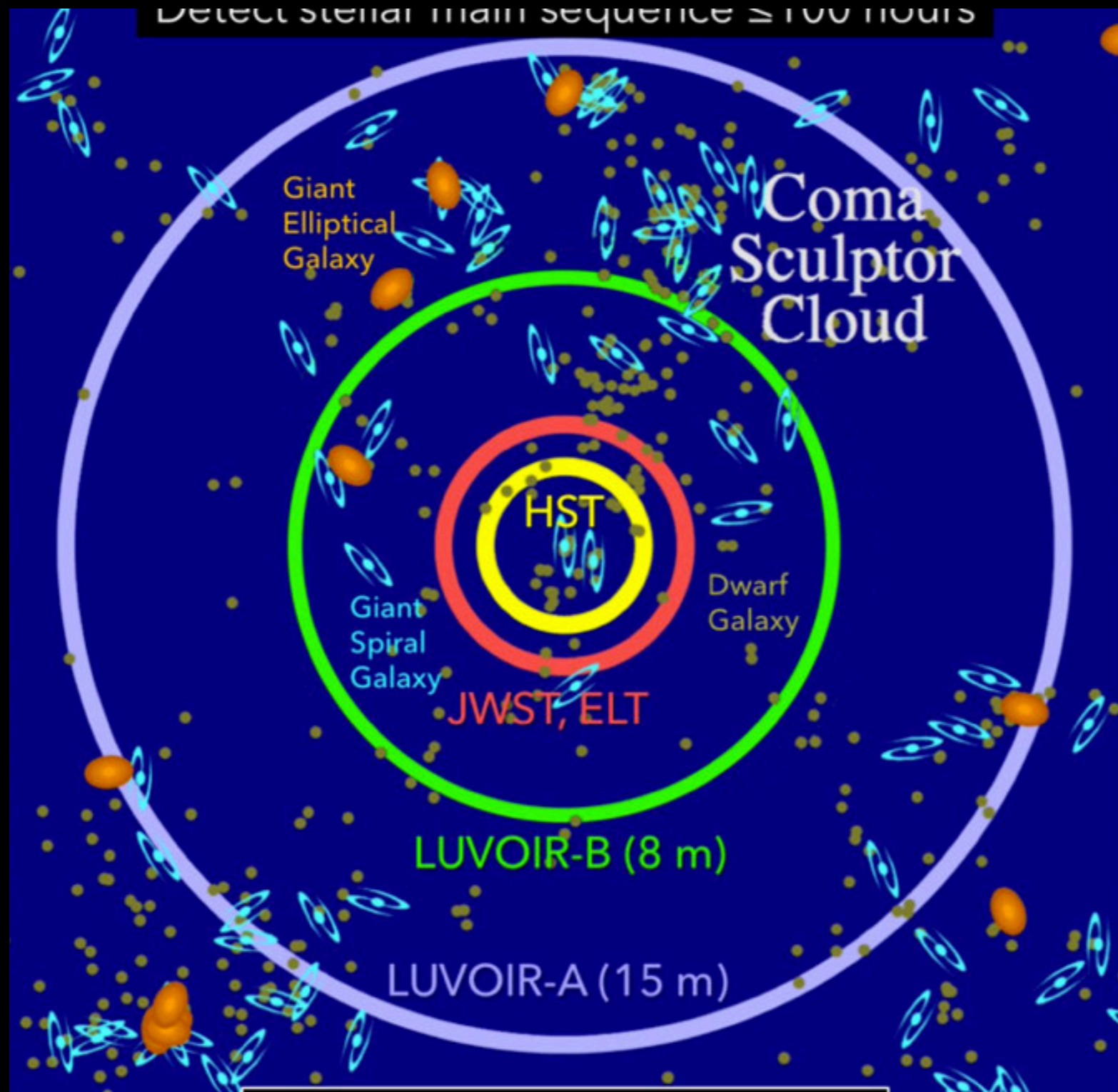
Planetary Spectrum Generator

Advanced tool for simulating spectra of Solar System bodies (with LUVVOIR and other telescopes).

OTHER TOOL BELTS

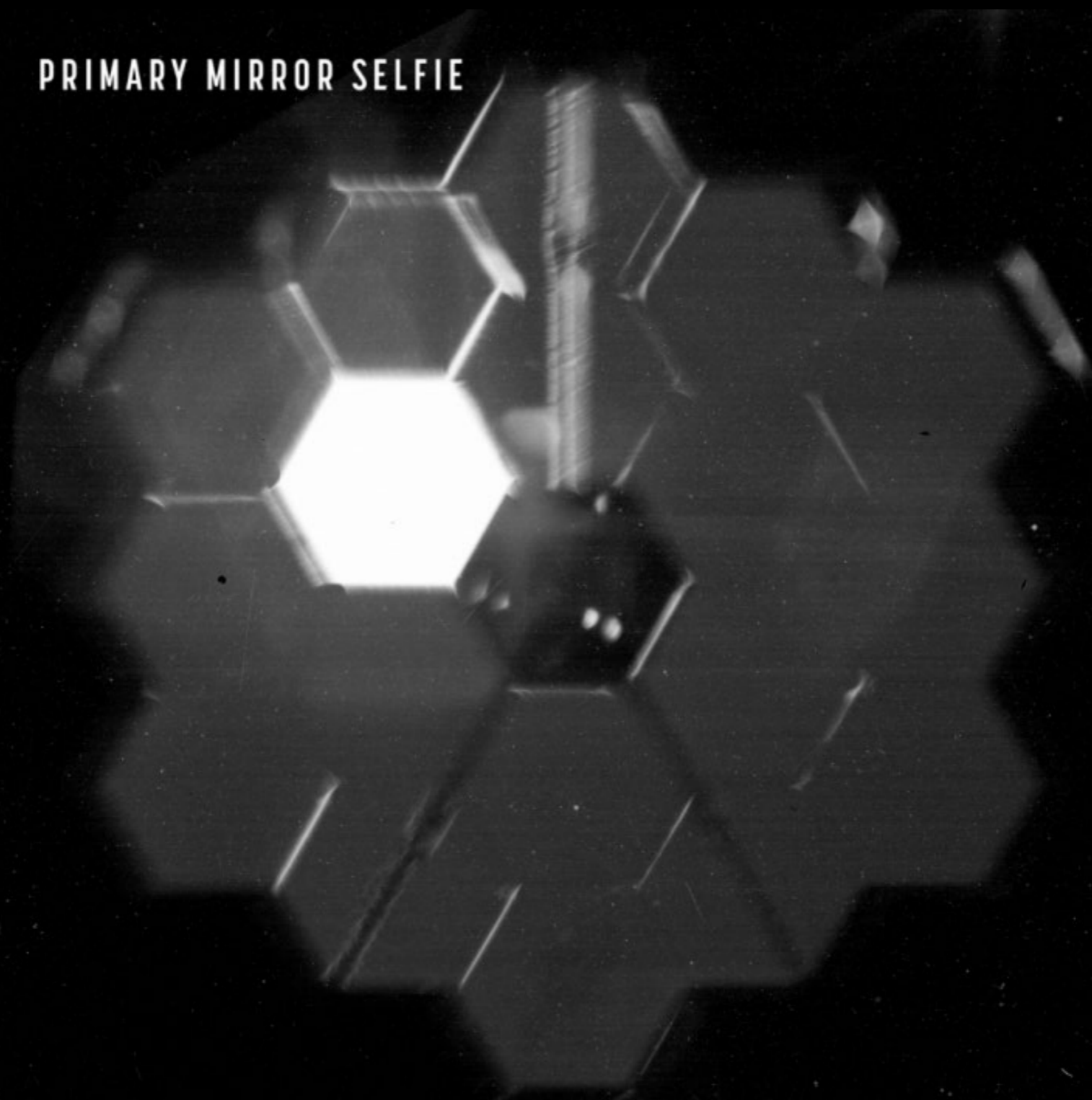


RESOLVE



PREPARE FOR THE UNKNOWN

PRIMARY MIRROR SELFIE



DISCUSSION

