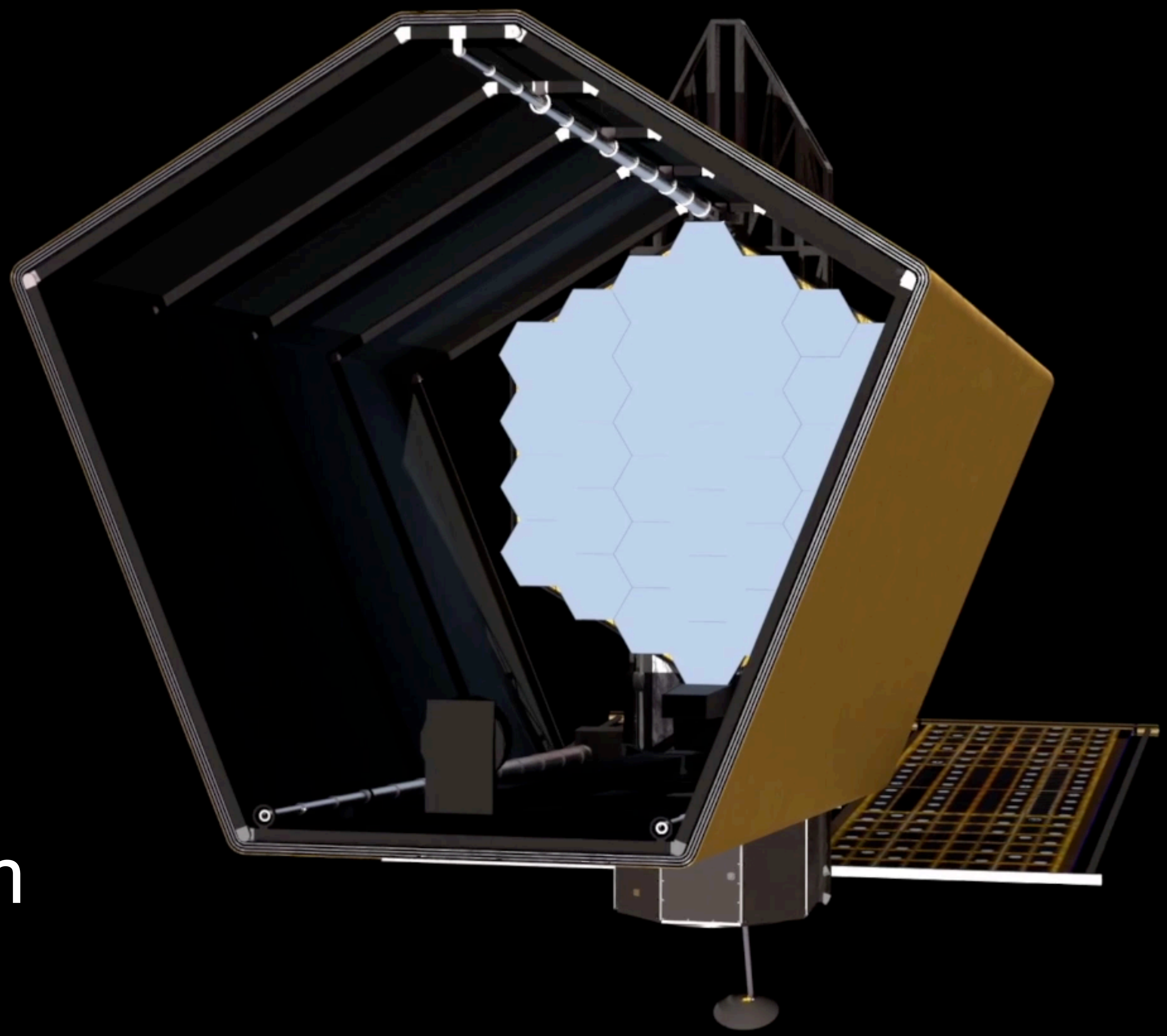
STScI | SPACE TELESCOPE SCIENCE INSTITUTE

Opportunties for Transformative Astrophysics with the Habitable Worlds Observatory

www.habitableworldsobservatory.org

Jason Tumlinson
STScI Head of Community Missions

What is HWO?



Notional HWO architecture

A super-Hubble to search for life in the universe and perform transformative astrophysics

Before we proceed, let us consider the words of the famous Italian astronomer. . .

"eppur si muove"

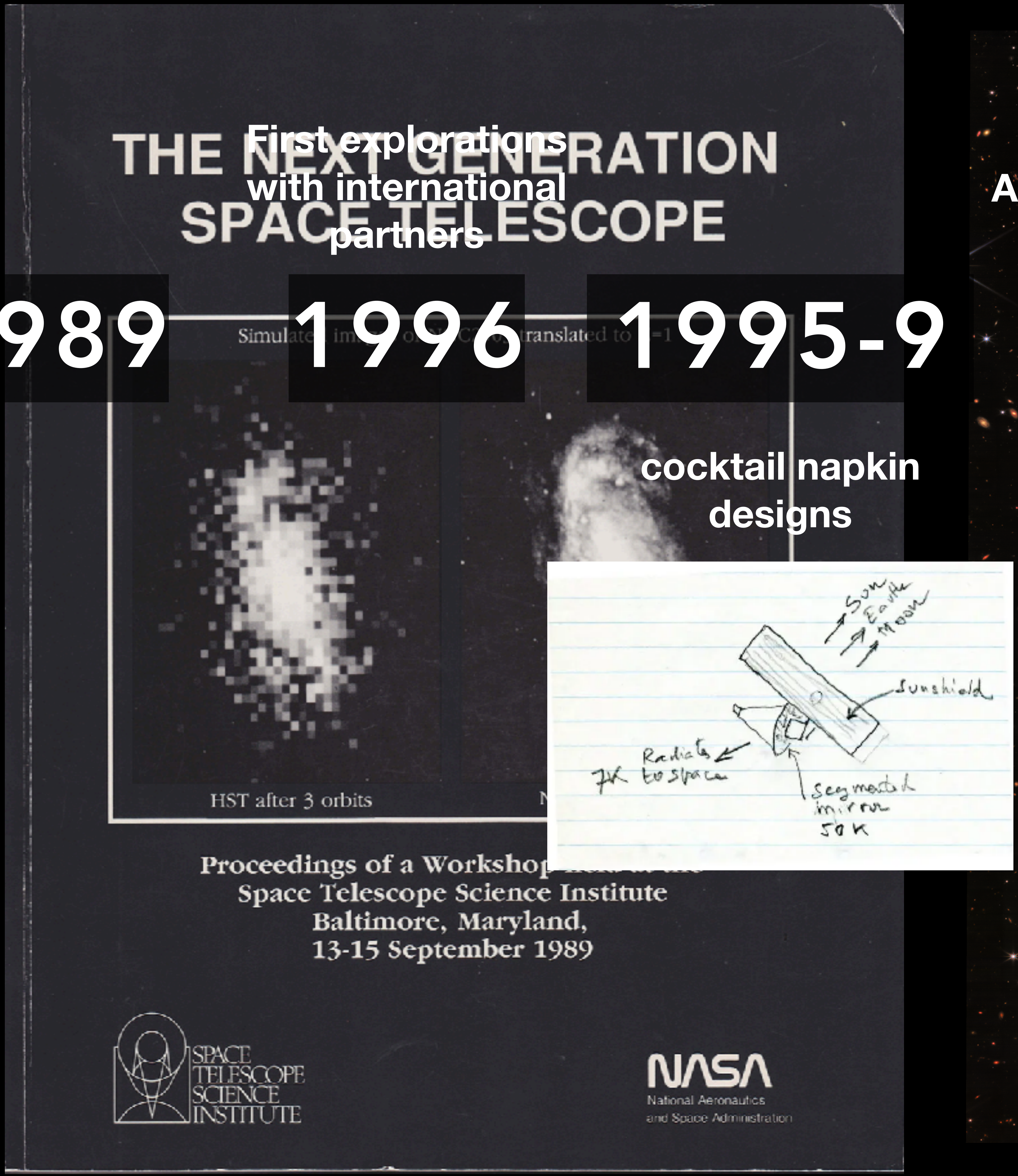
Galileo Galilei

To succeed with flagships requires
vision, optimism, patience, and teamwork.

Duccio Macchetto

head of ESA @ STScI 1970s-2008

Vision, Teamwork, Optimism & Patience: The Elements of Success



1989

1996 First explorations with international partners

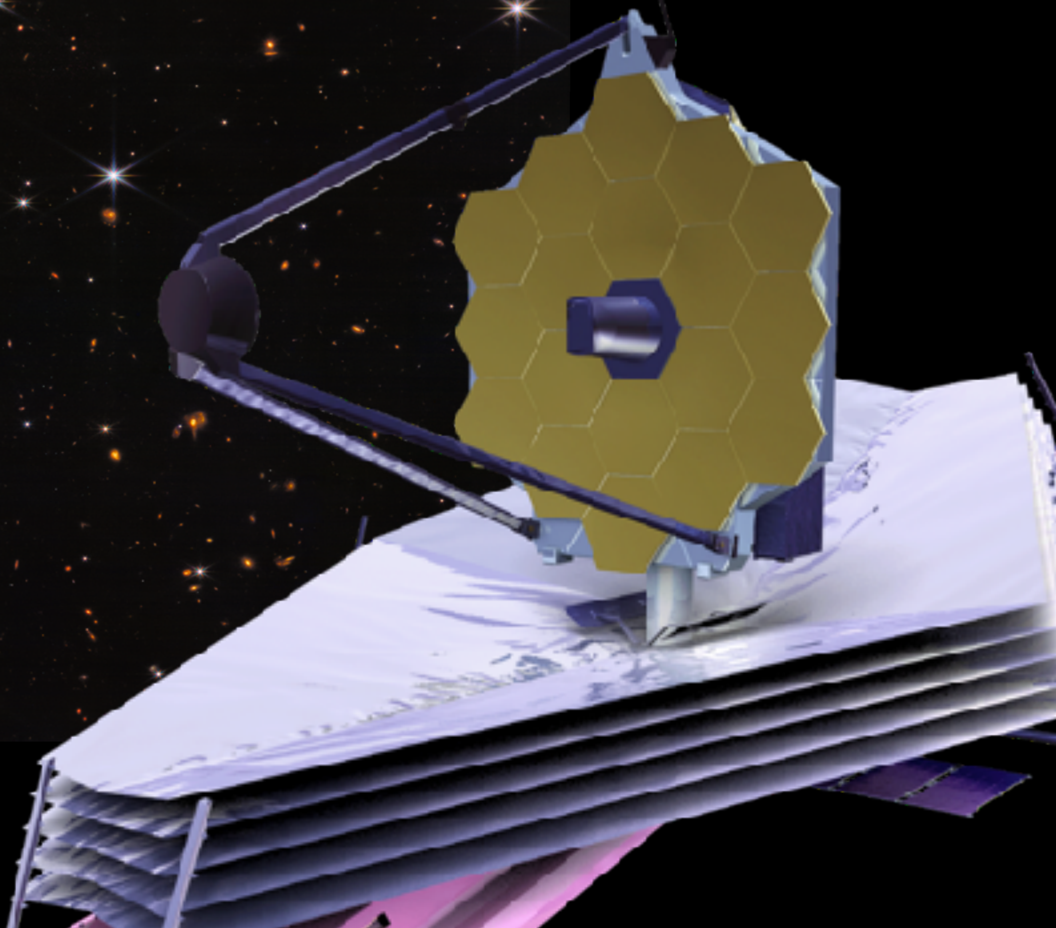
1995-9 cocktail napkin designs

2002 Ariane V launcher selected

2003 European & Canadian Instruments Selected (MIRI, NIRSpec, NIRISS)

2013 Instruments delivered

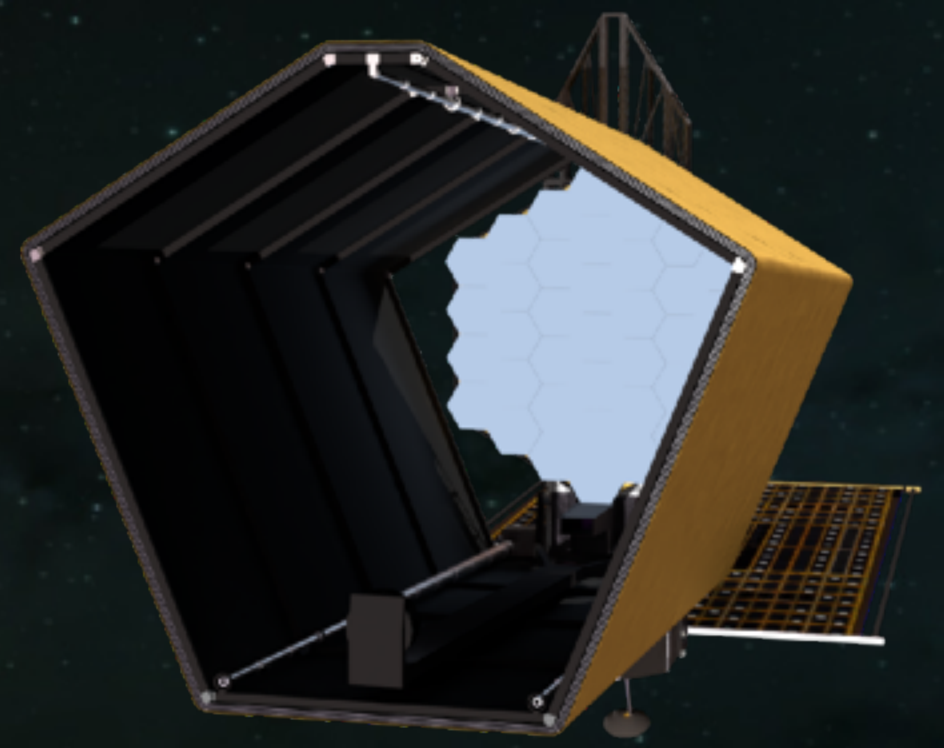
2021 launch from French Guyana



Revolutionary Telescope and Instruments

Telescope

Diameter	~6.0 m (inner)
Bandpass	~100–2500 nm



Fourth Instrument

To be defined

Coronagraph

High-contrast imaging and imaging spectroscopy

Bandpass	~200–1800 nm
Contrast	~1e-10
	Vis: ~140 NIR: ~70, 200

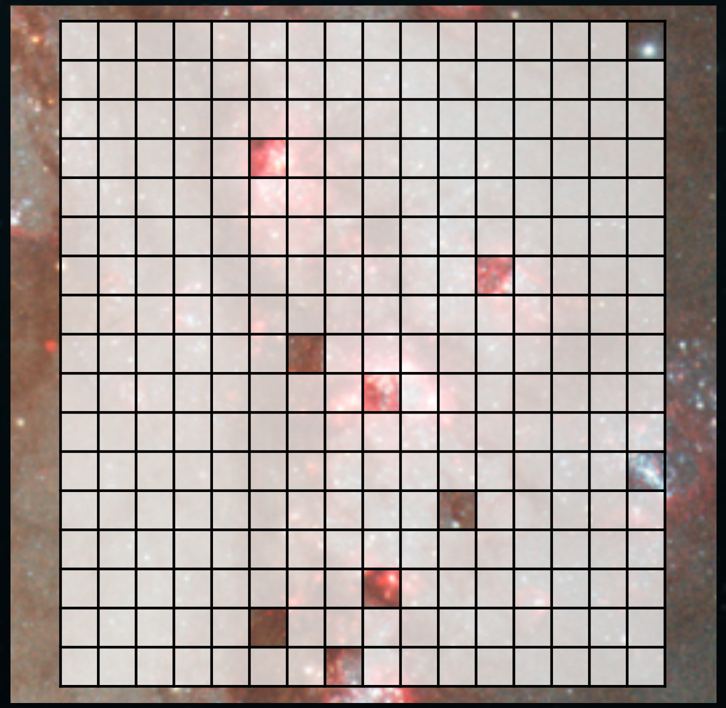
High-Resolution Imager

UV/Vis and NIR imaging	
Bandpass	~200–2500 nm
Field-of-View	3x2 arcmin
~67 science filters + grism	
High-precision astrometry?	

UV Multi-Object Spectrograph

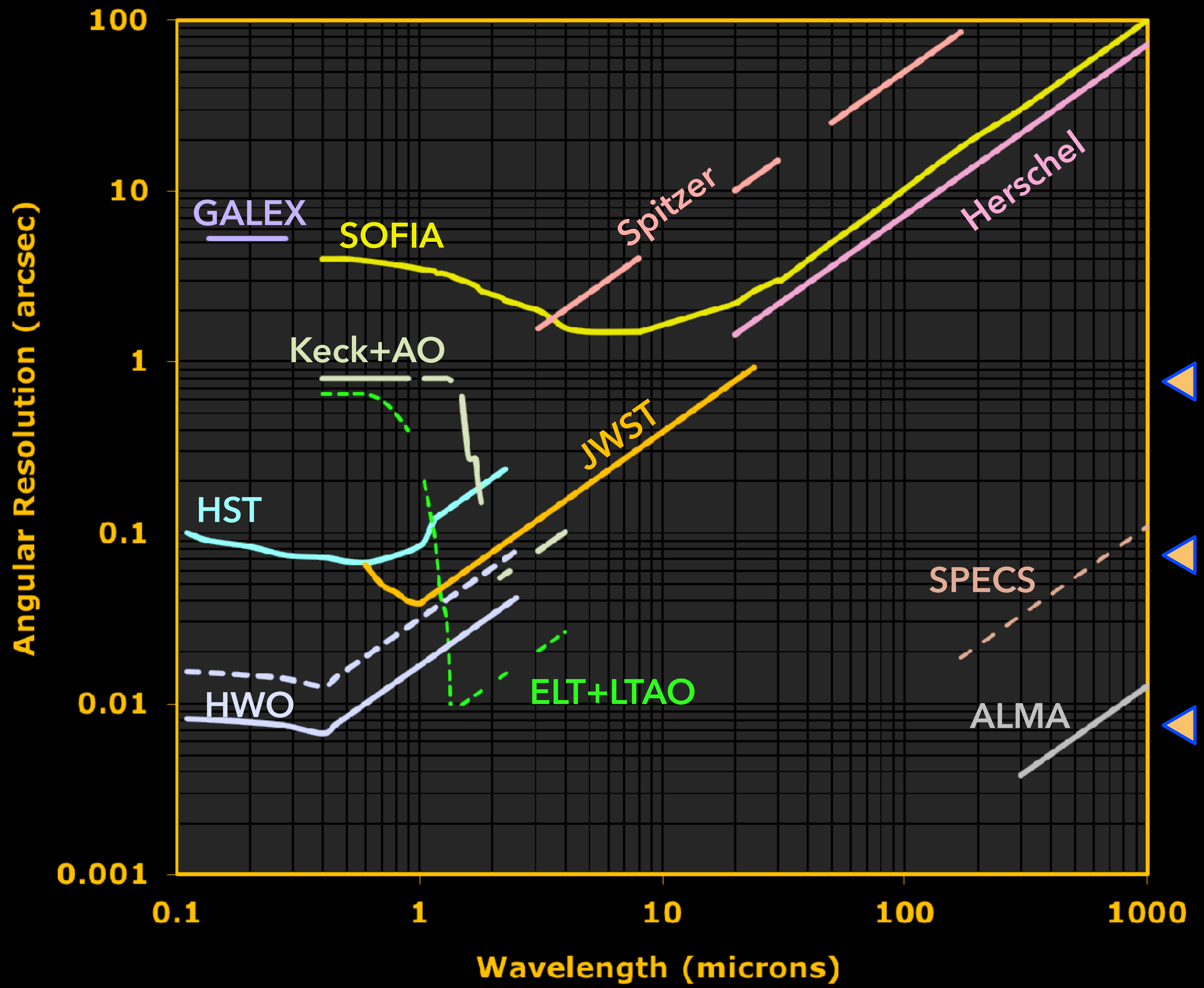
UV/Vis multi-object spectroscopy and FUV imaging

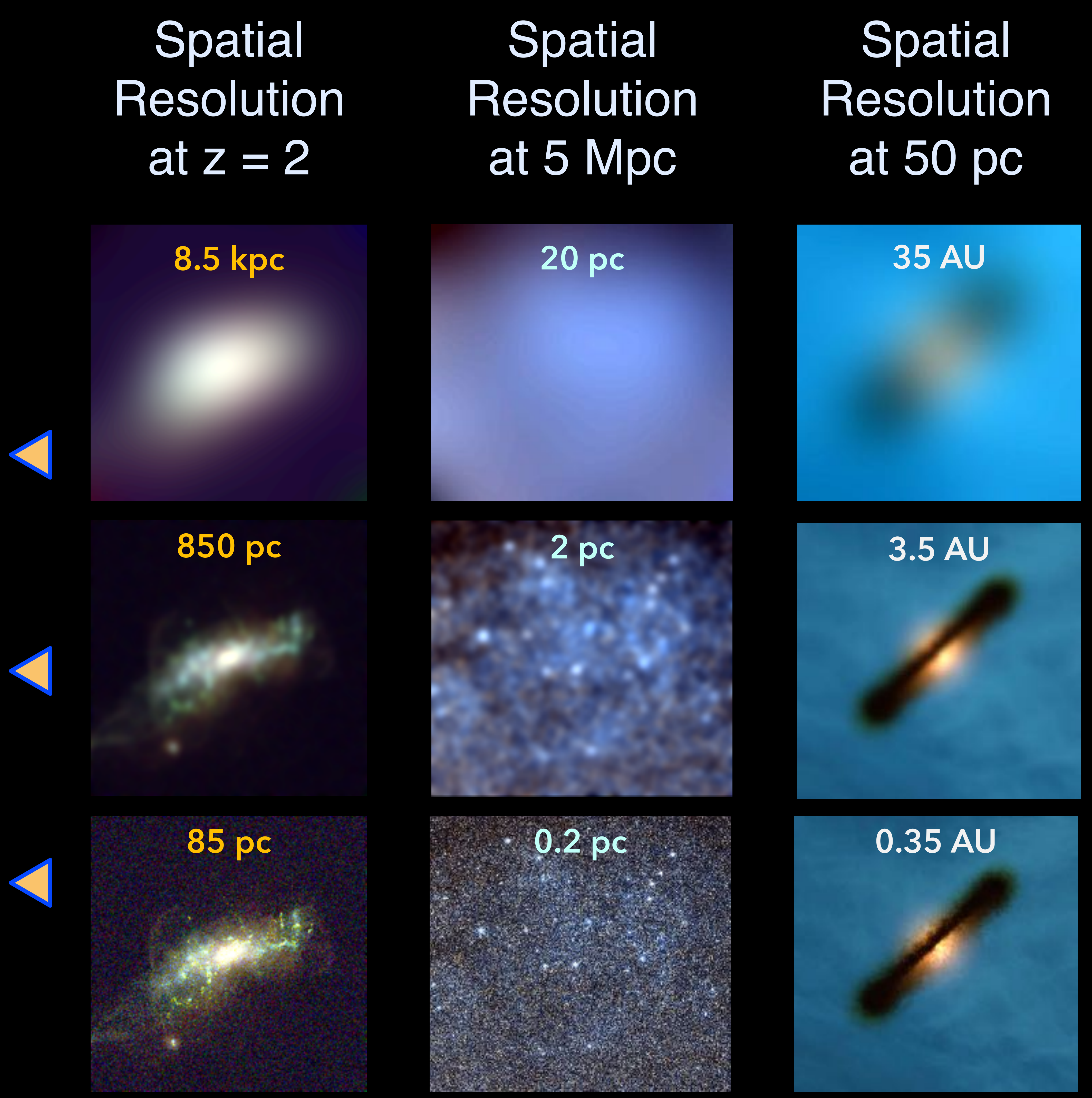
Bandpass	~100–1000 nm
Field-of-View	2x2 arcmin
Apertures	0.2 x 0.1 sec
Resolution	500–50,000



Unprecedented Depth!

Unprecedented Resolution!

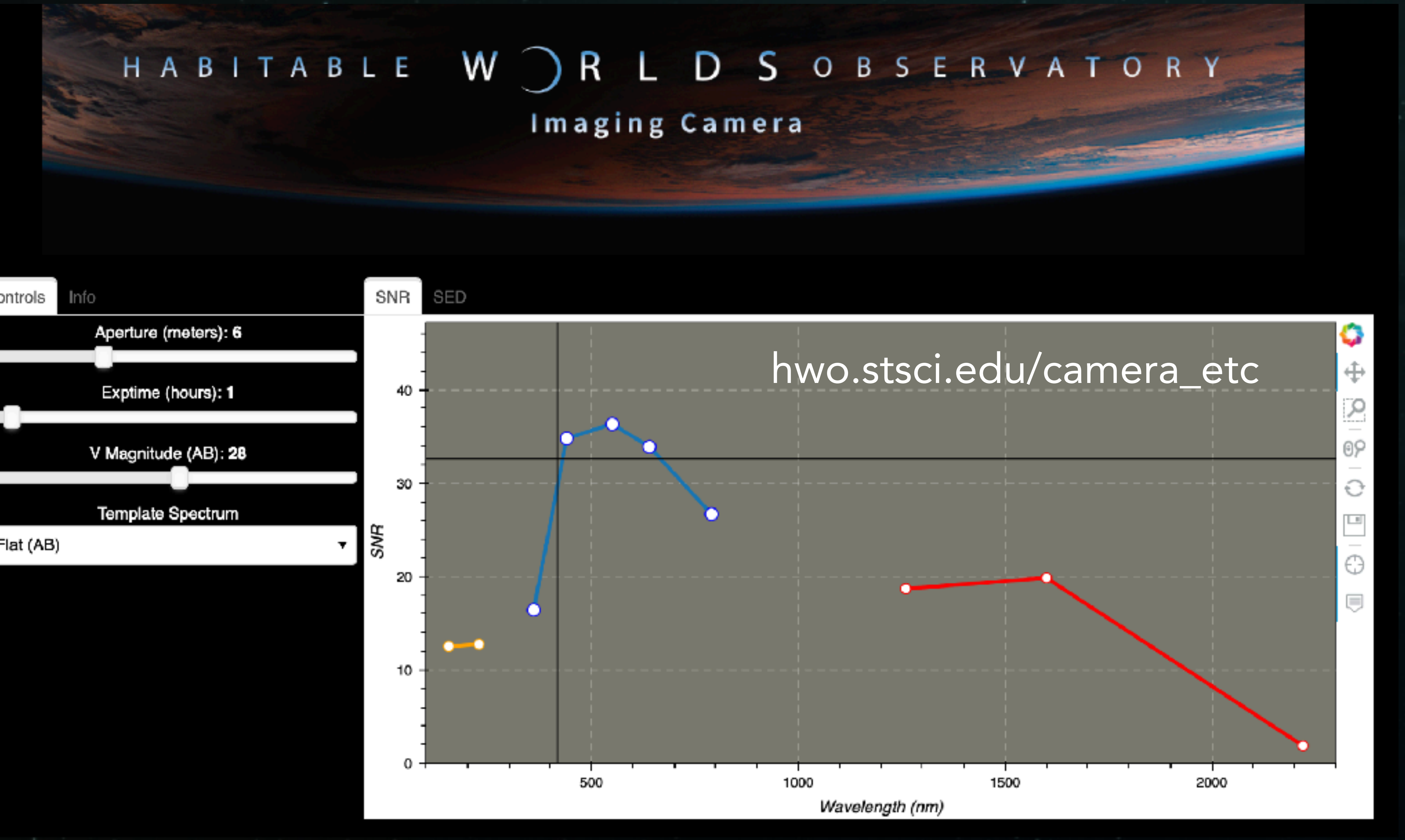


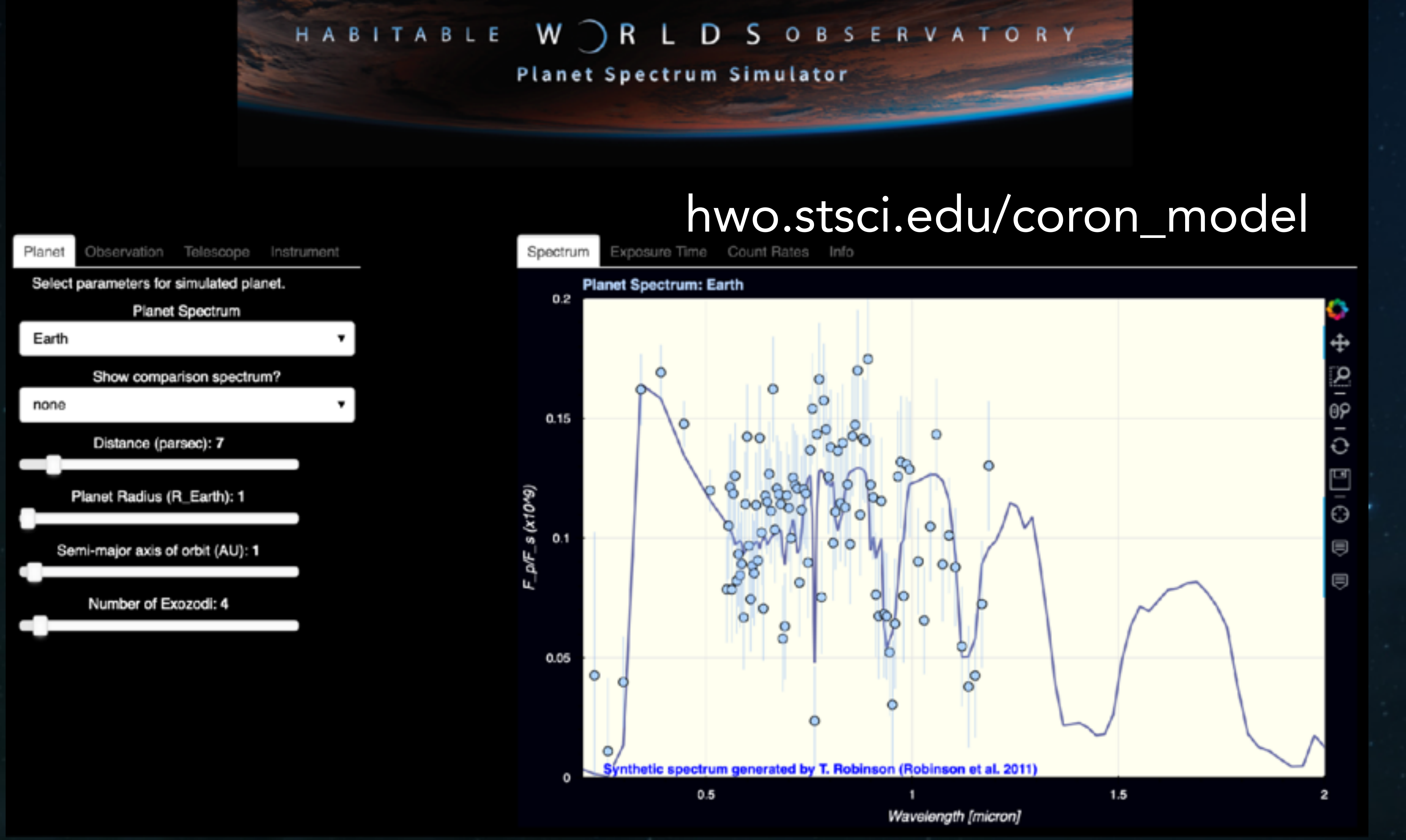


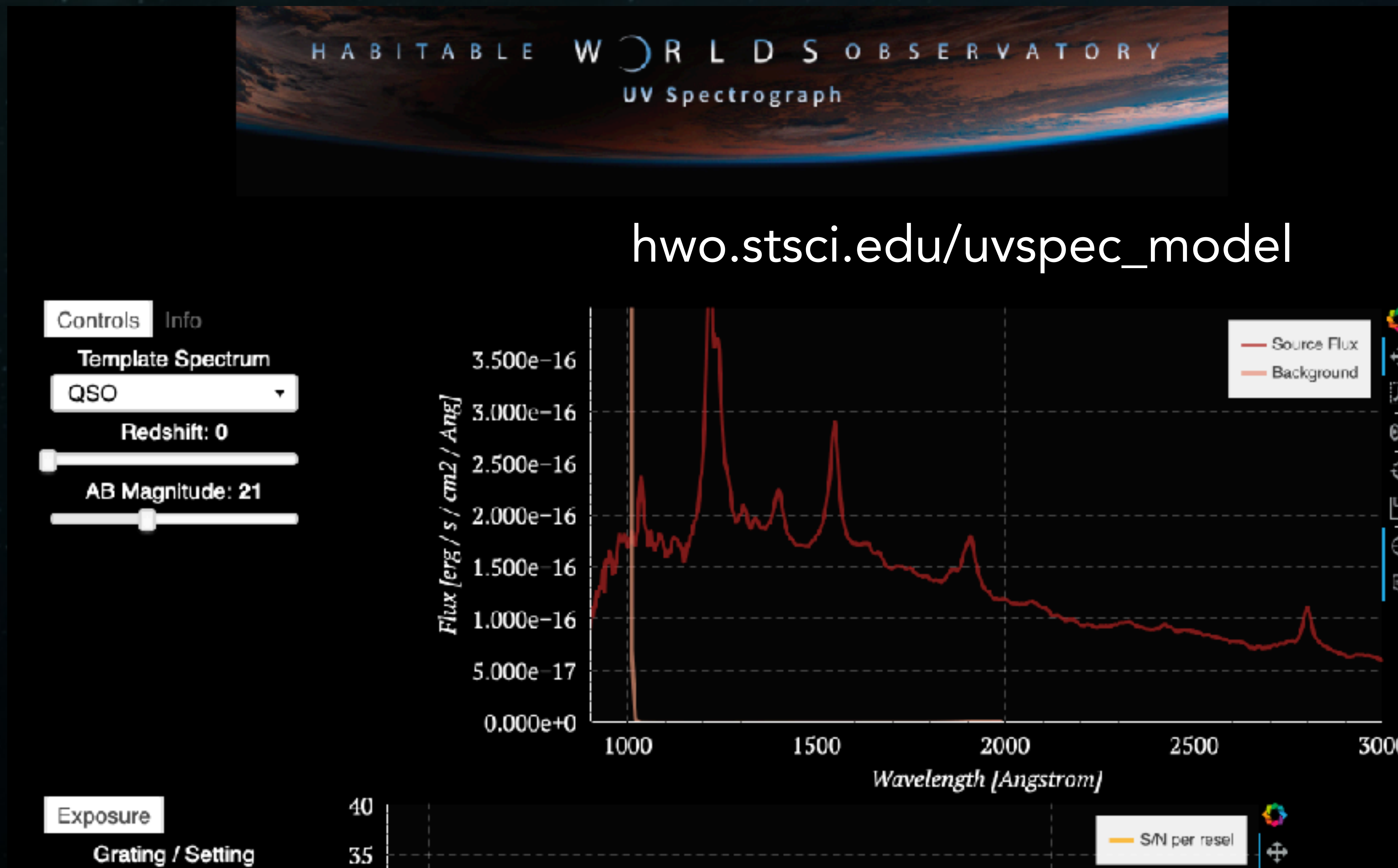
HWO will resolve galaxies to ~200 parsec scales at any redshift!

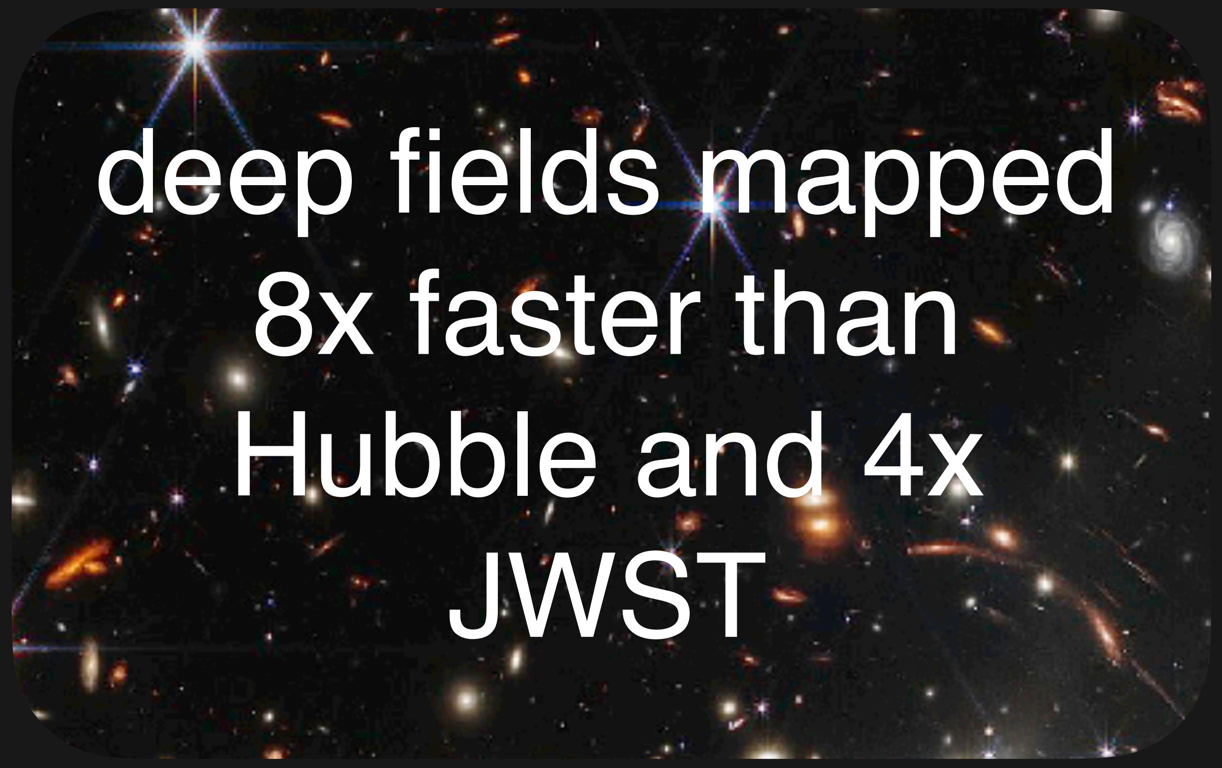
Open source community ETC tools

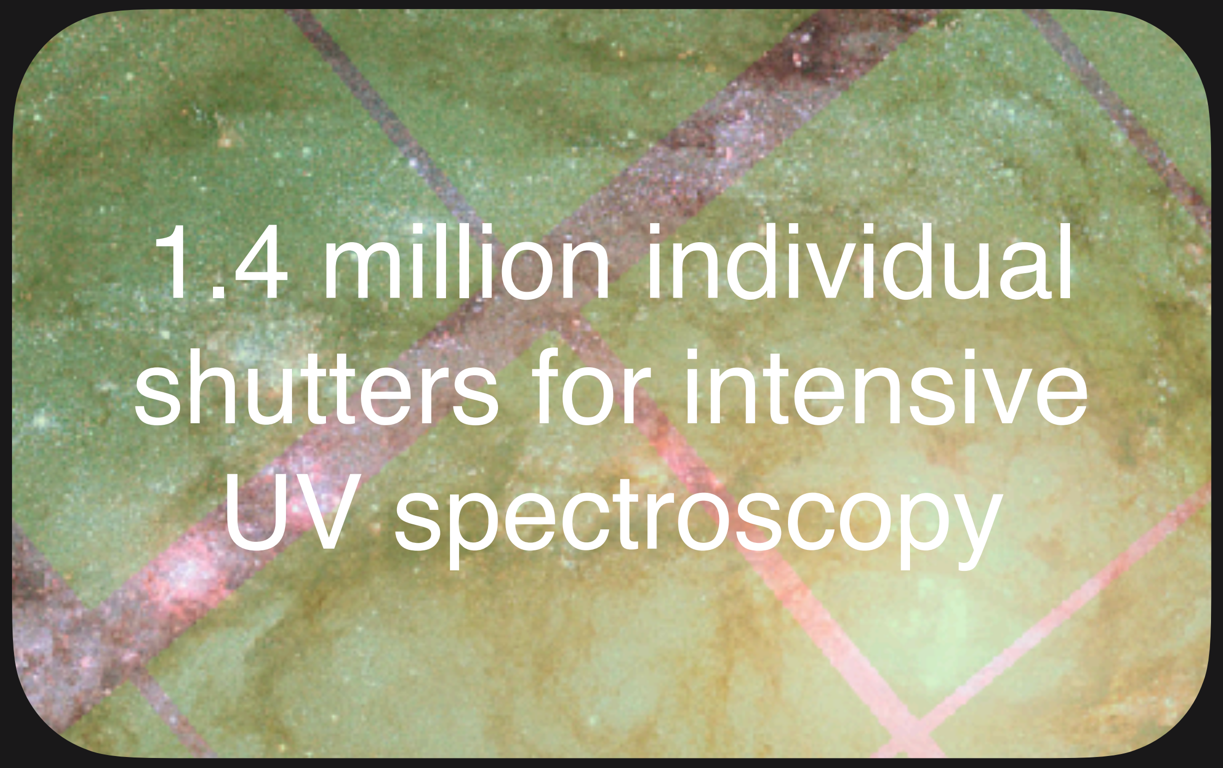
hwo.stsci.edu

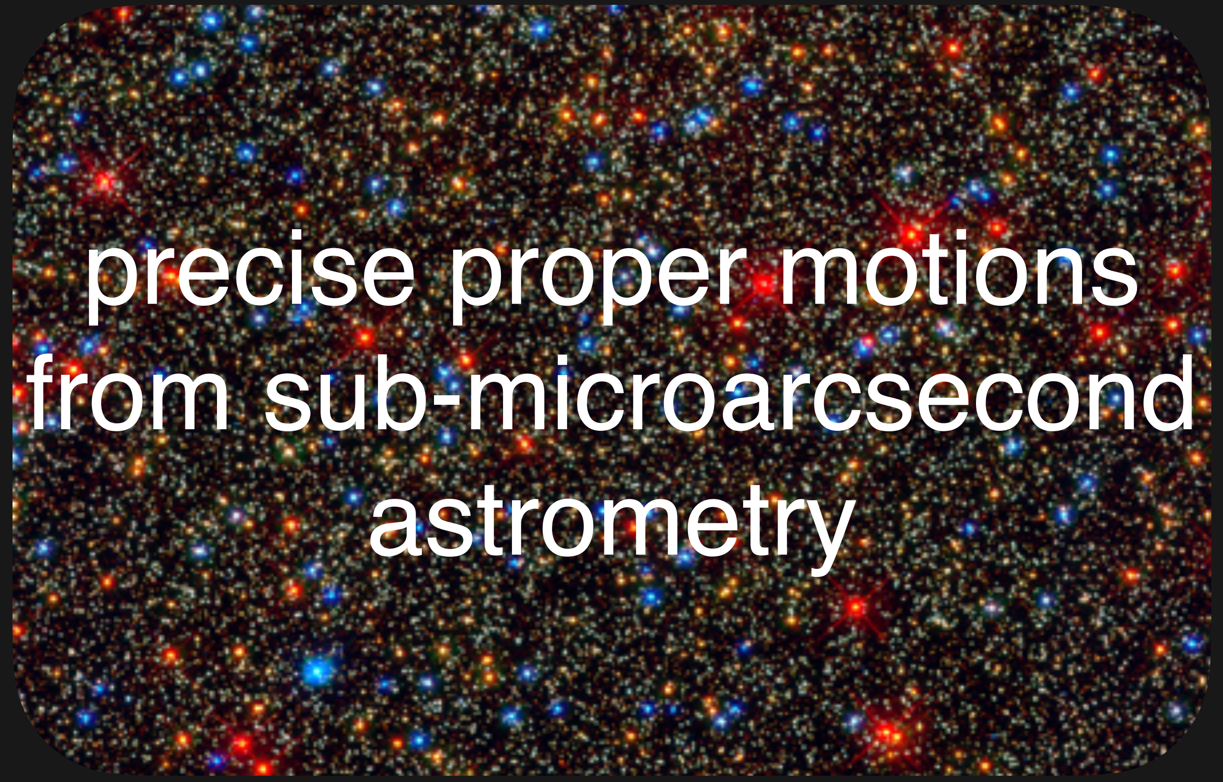


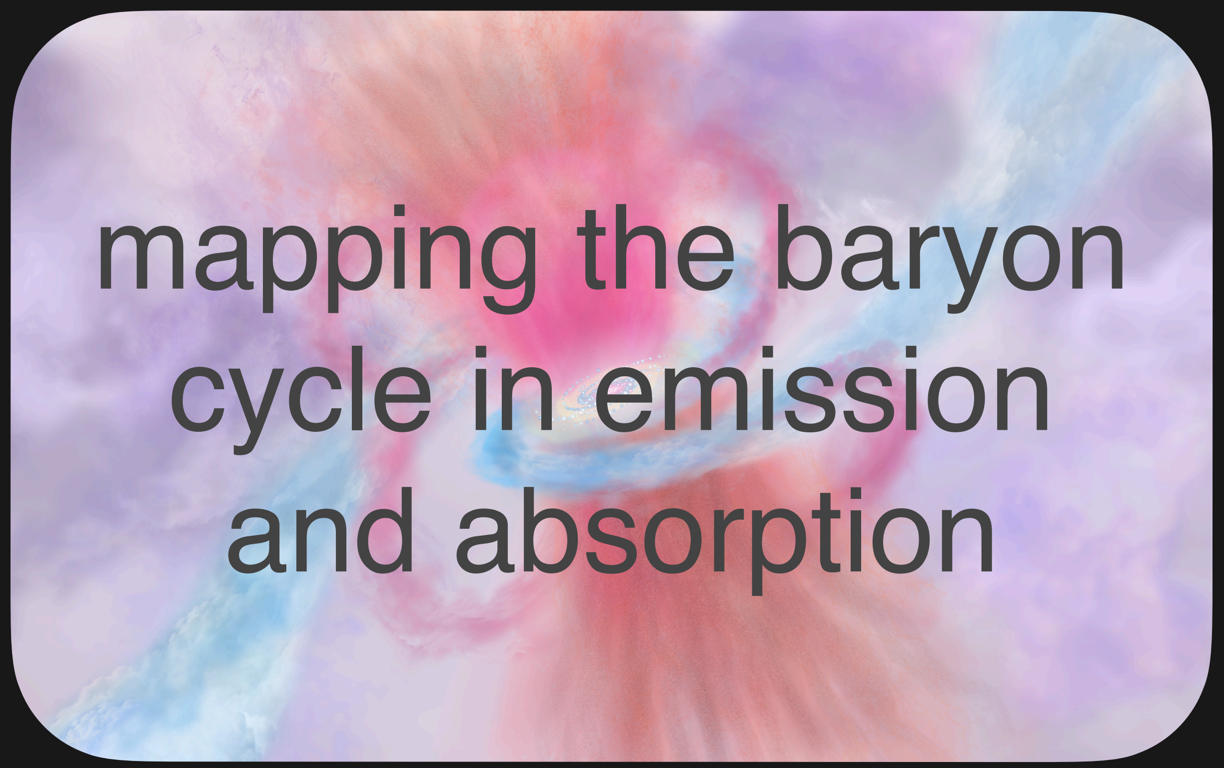


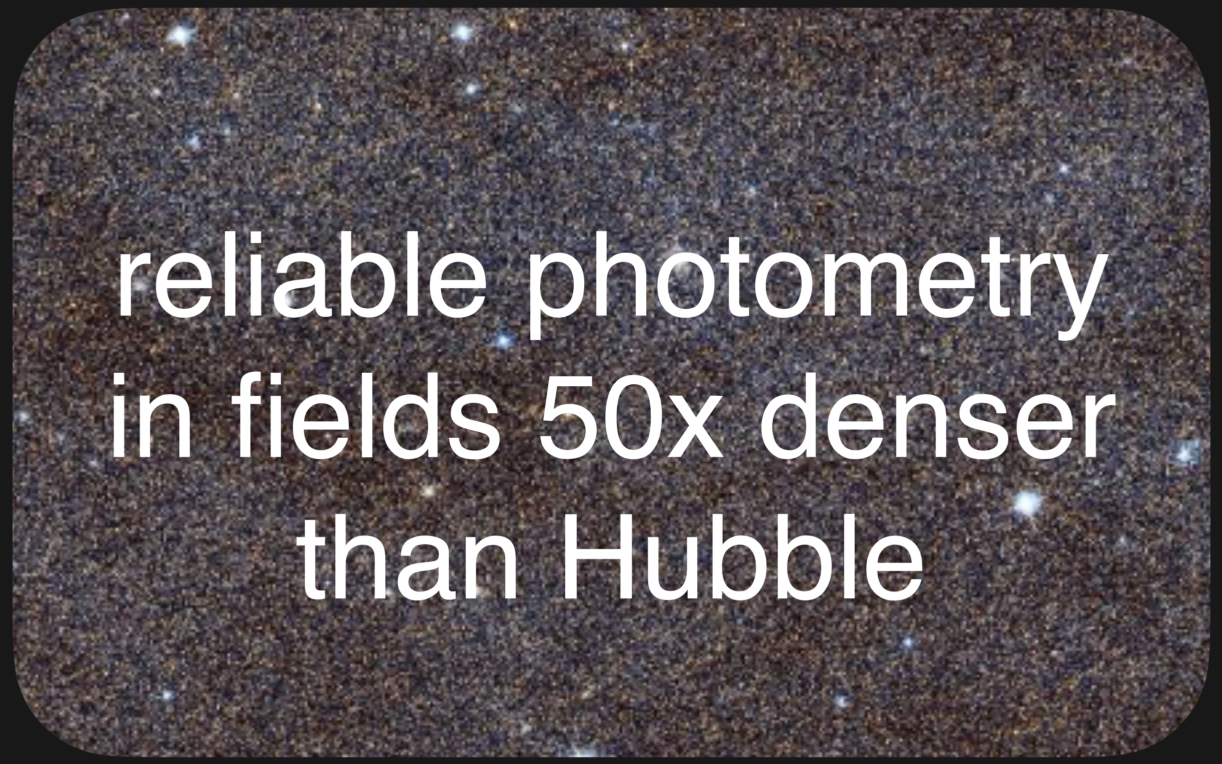






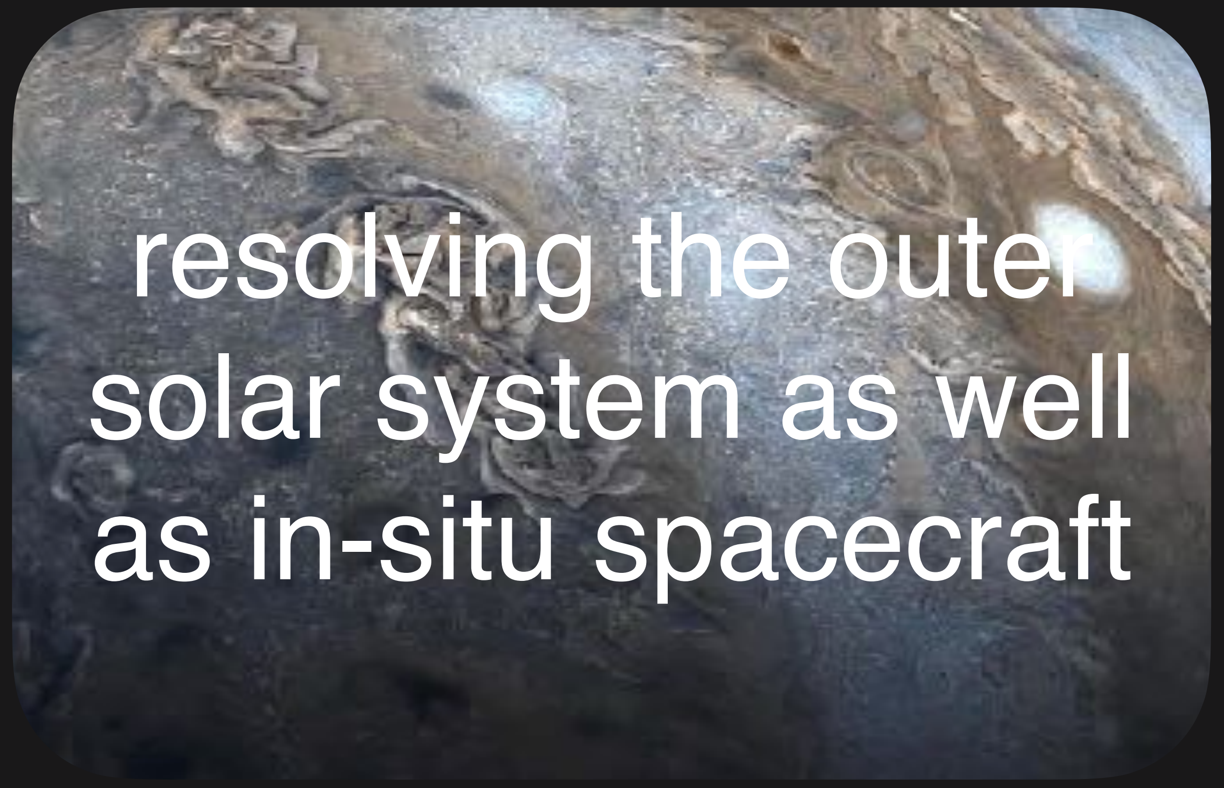


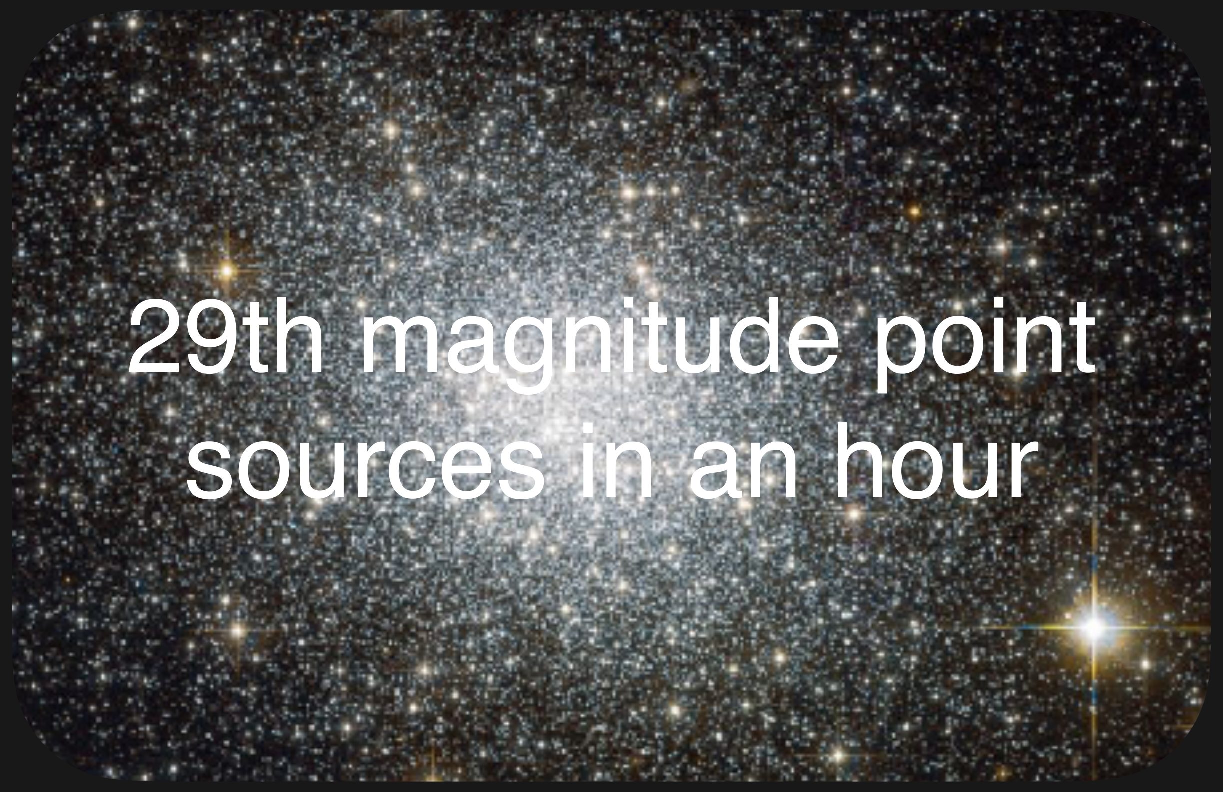




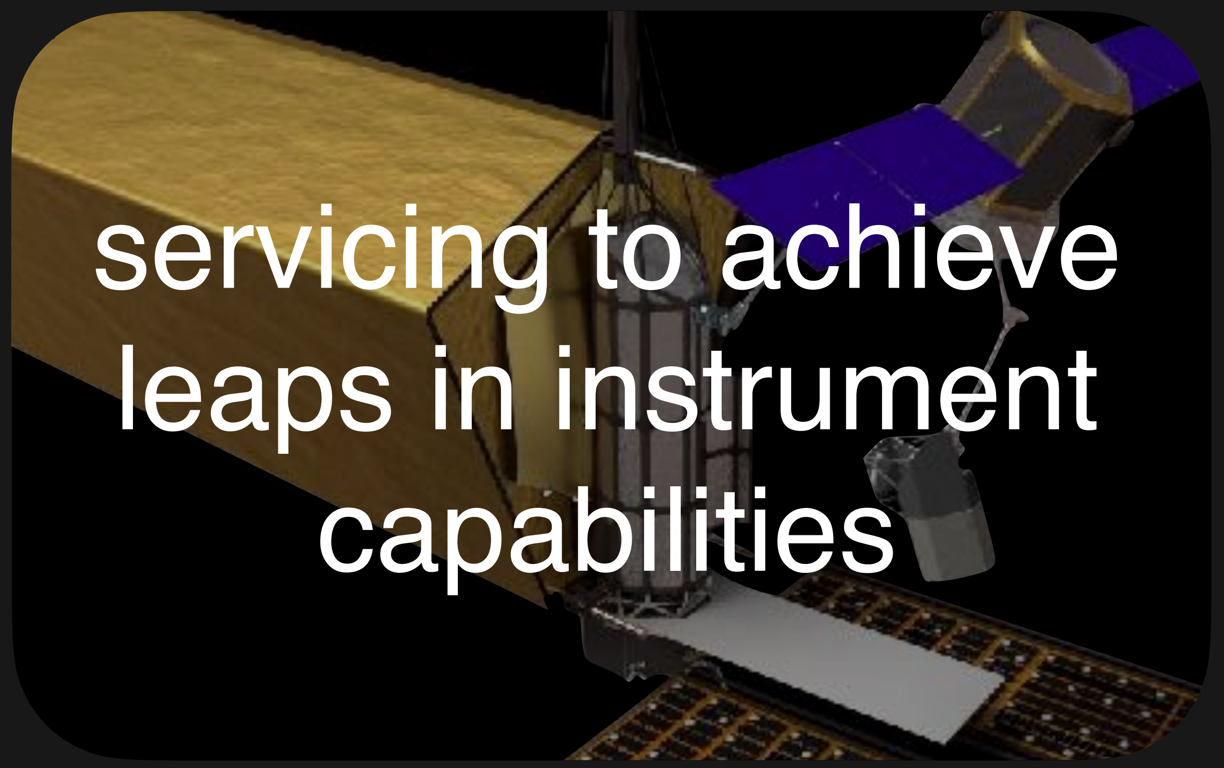
HABITABLE WORLDS OBSERVATORY

Transformative Astrophysics Capabilities





Your idea here!

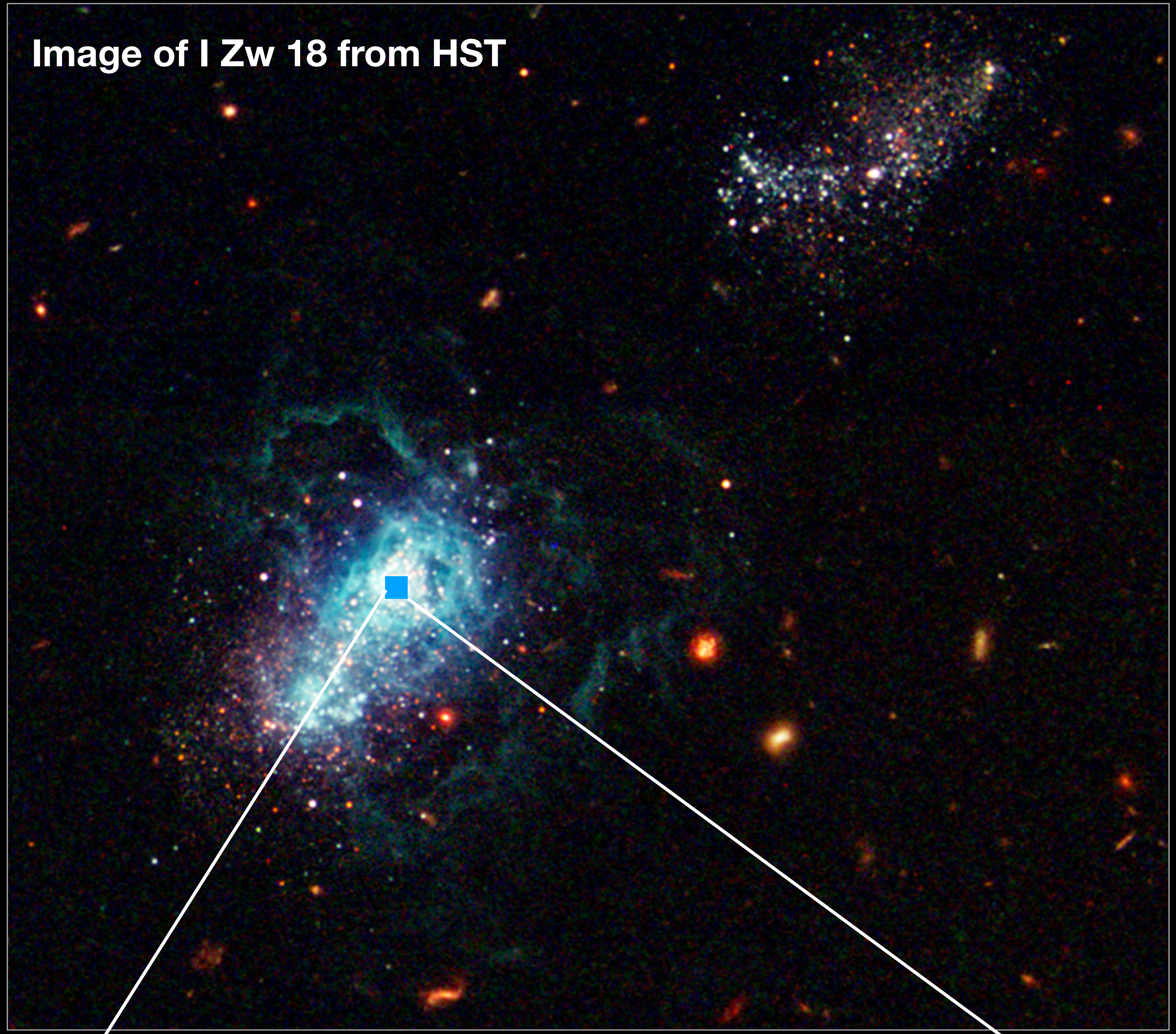


he Most Chemically Primitive Stars

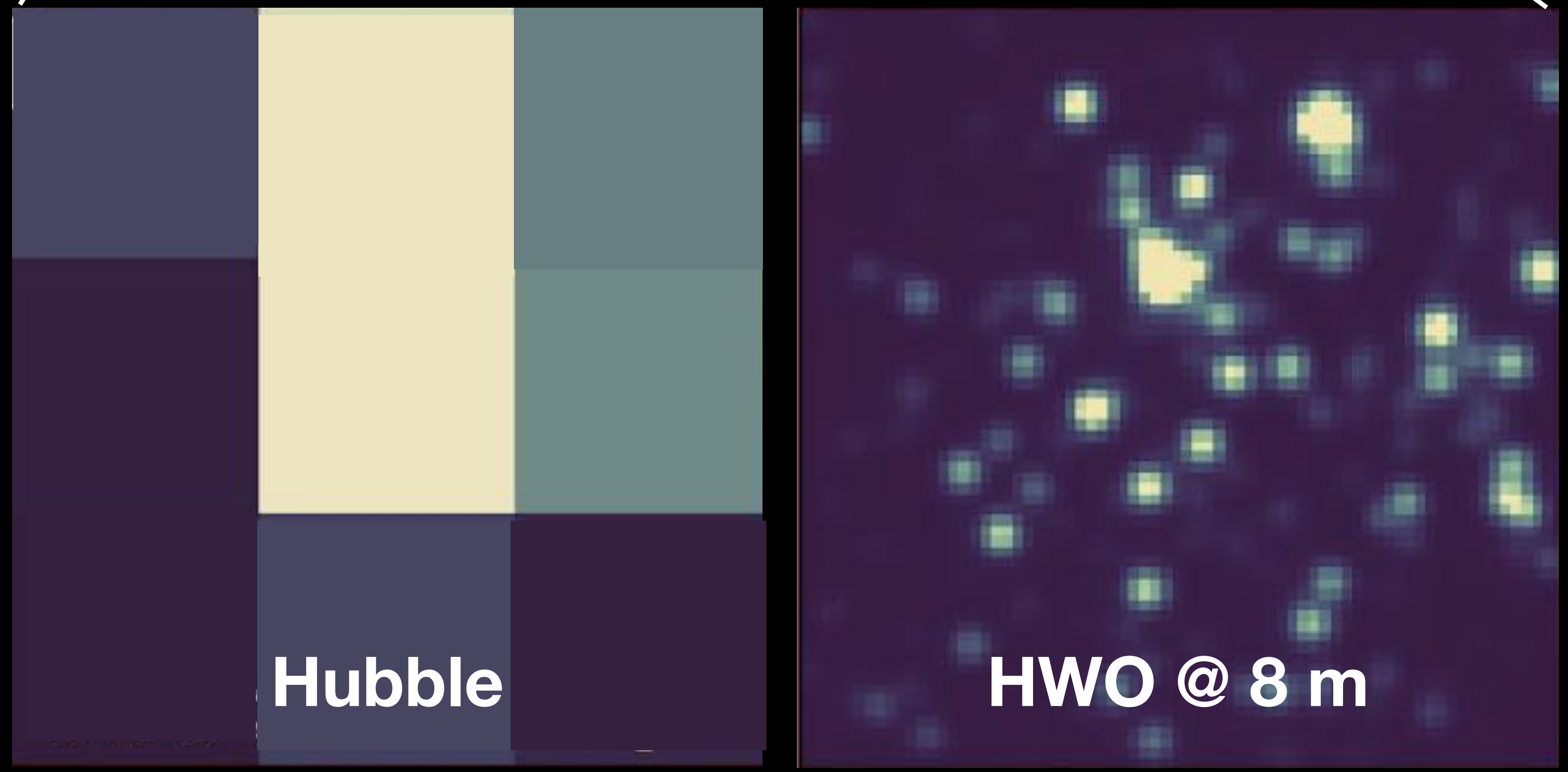
- Massive stars produce most of the common heavy element (C, N, O).
- Early in cosmic history, these massive stars may have lived and died in a manner very different from today.
- The metal-poor galaxy I Zwicky 18 is one of the few places in the local Universe where we can observe individual massive stars that are chemically primitive.

Only HWO:

- can resolve massive, clustered stars at UV wavelengths where they emit most of their radiation.
- measure temperature, mass, metal content, and age for these unique stellar populations.
- Hubble lacks the resolution and JWST & Roman lack the UV sensitivity to perform these observations.



The center of I Zw 18 as seen by

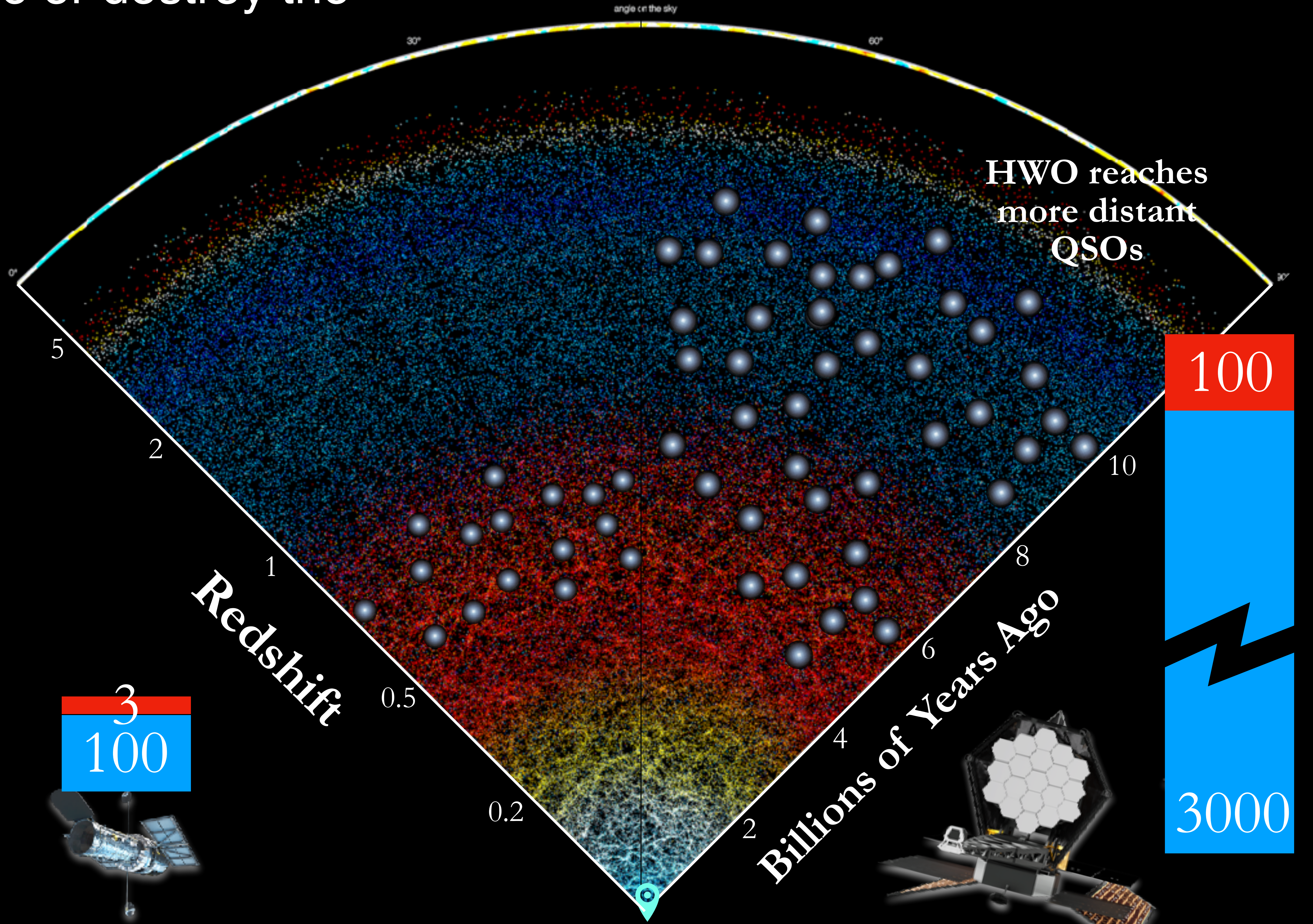


Why Do Massive Galaxies Stop Forming

- The most massive galaxies are "quenched" - they have ceased to form stars.
- HWO will address this complex multi factor question from many angles.
- One potential causal factor is that the galaxies lose or destroy the
- Astronomers can view the extremely diffuse gas in the CGM by using a background source - a distant quasar - to observe absorption.

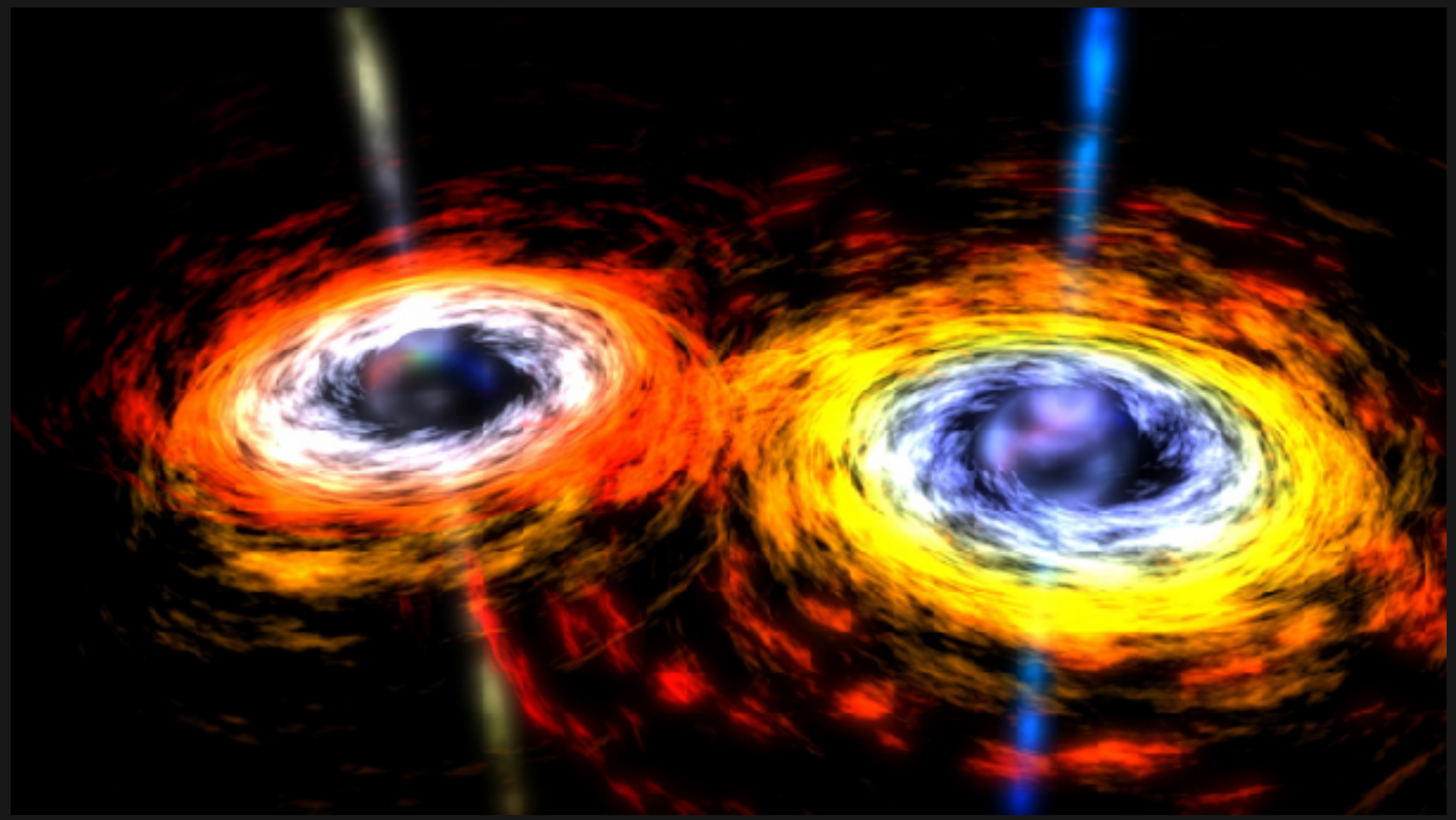
Only HWO:

- can reach enough distant sources to observe the CGM of more than 100 galaxies while their quenching is underway.
- HST is severely limited by its size and JWST does not observe UV wavelengths where the gas appears.

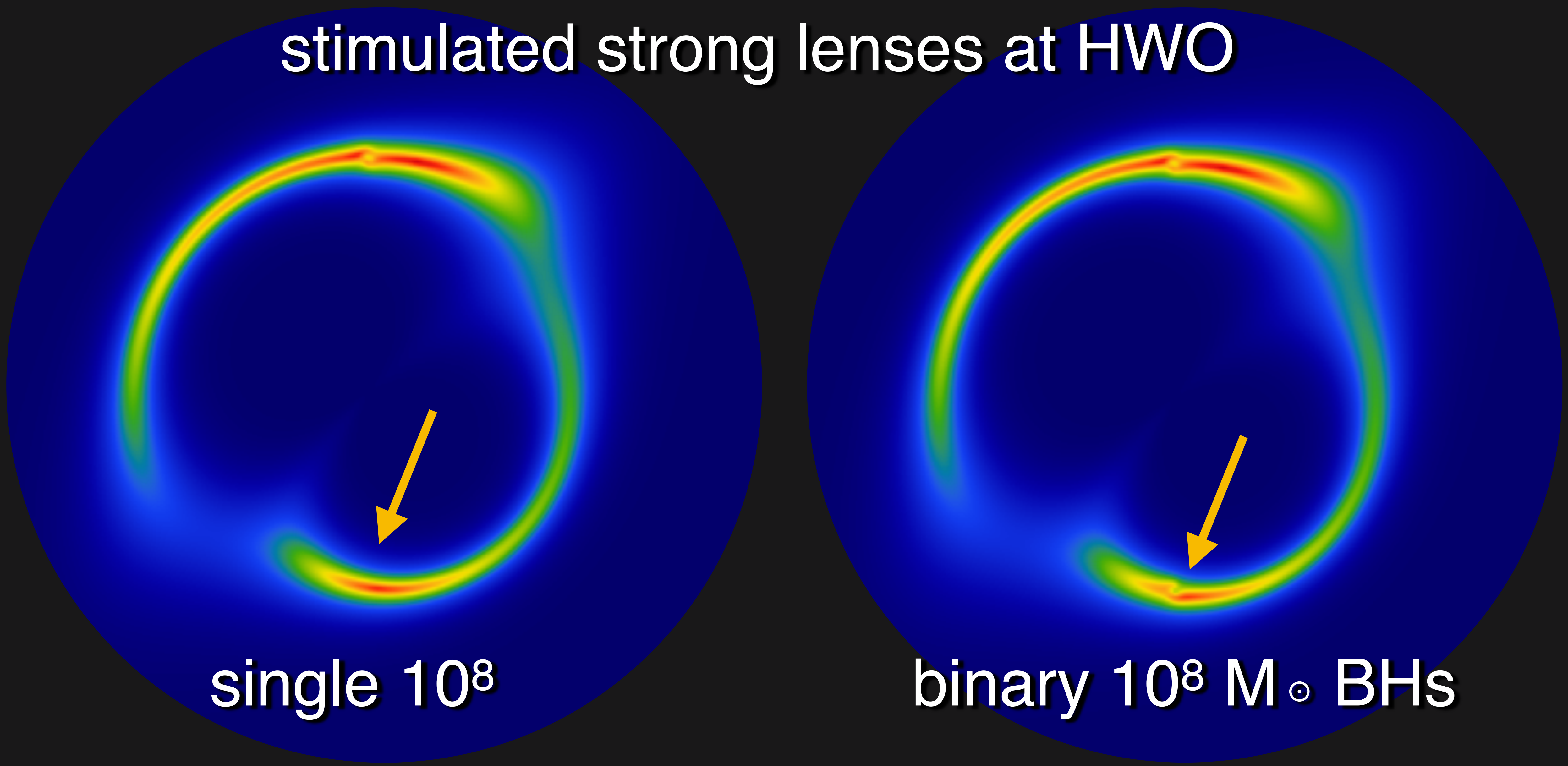


Timing the mergers of the largest black

- the largest black holes in the centers of galaxies form in galaxy mergers.
- the massive black holes can take much longer to merge than the galaxies containing them, up to a billion years.
- a binary black hole in a galaxy acting as a gravitational lens imprints subtle features into the image of the background



NASA Vis Studio render of merging supermassive black holes



Only HWO:

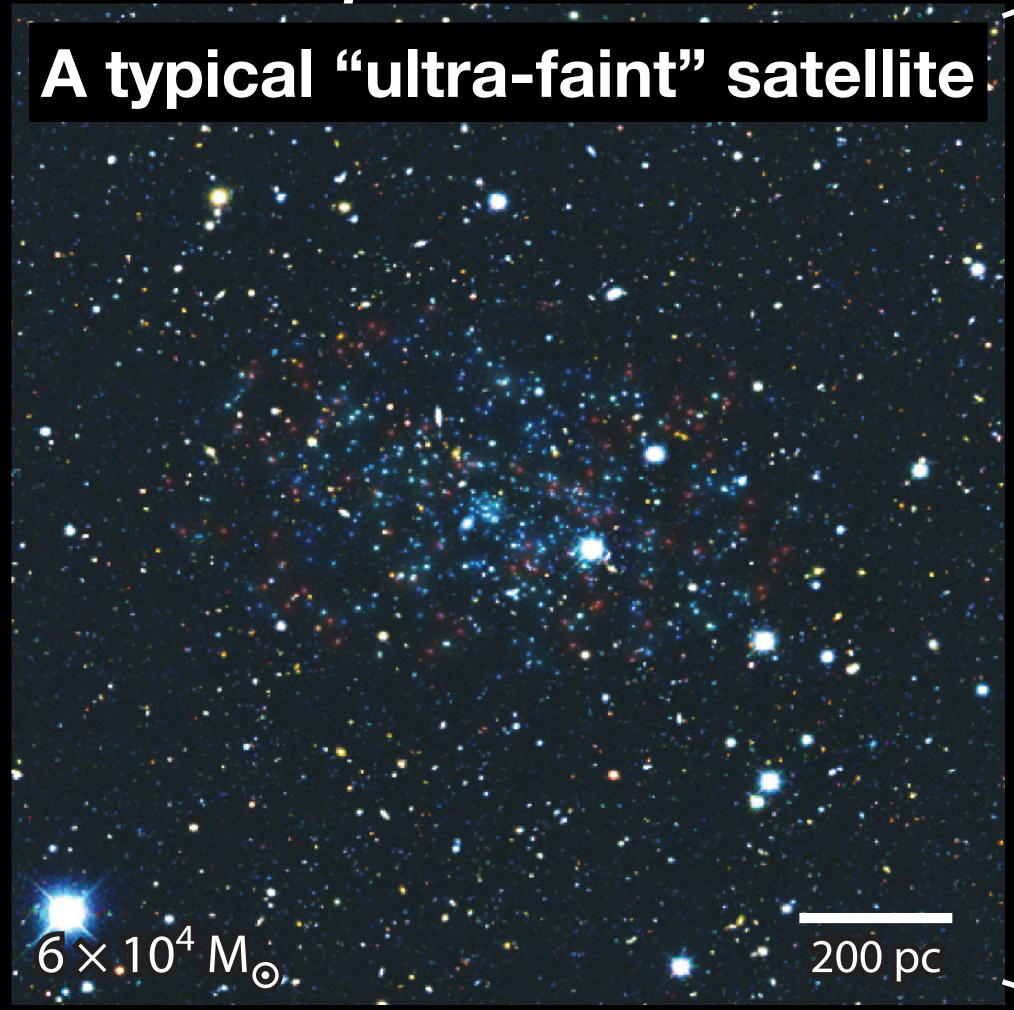
- can constrain the timescales of SMBH mergers with 1000 strong lenses discovered in Roman and other all-sky surveys
- has optical imaging resolution and PSF stability sufficient to sample ~1000 systems in ~100 hours.
- Hubble lacks the resolution and JWST lacks the sensitivity to perform these observations.

What is the mass of the Dark Matter

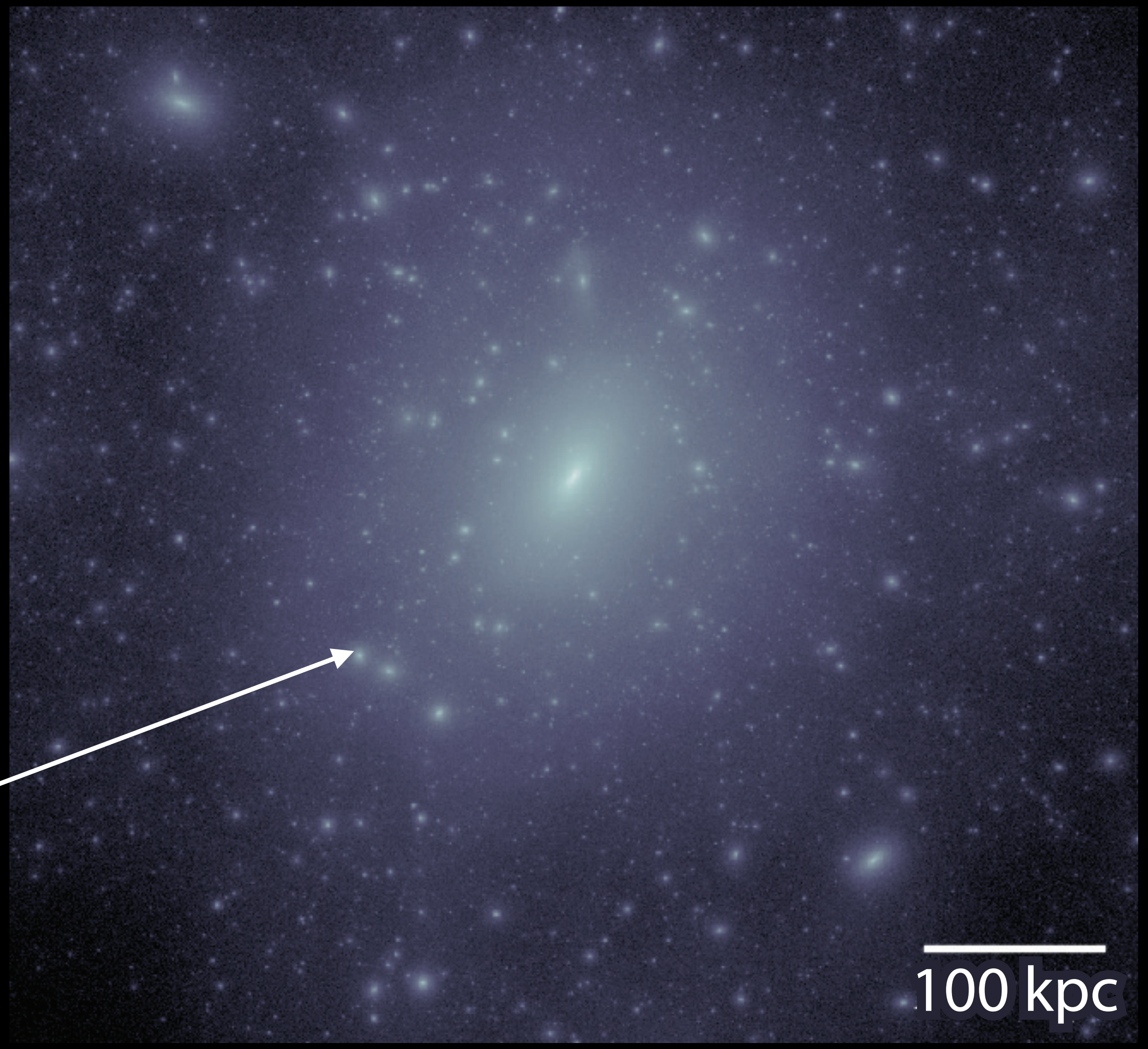
- Dark Matter makes up about 1/3 of the cosmos, but we do not know what it is.
- structure formation theory holds that all galaxies live in 'halos' made of dark matter, but the smallest halos are sensitive to the mass/energy of the DM particle.
- we can constrain the energy of the DM particle by counting the smallest

Only HWO:

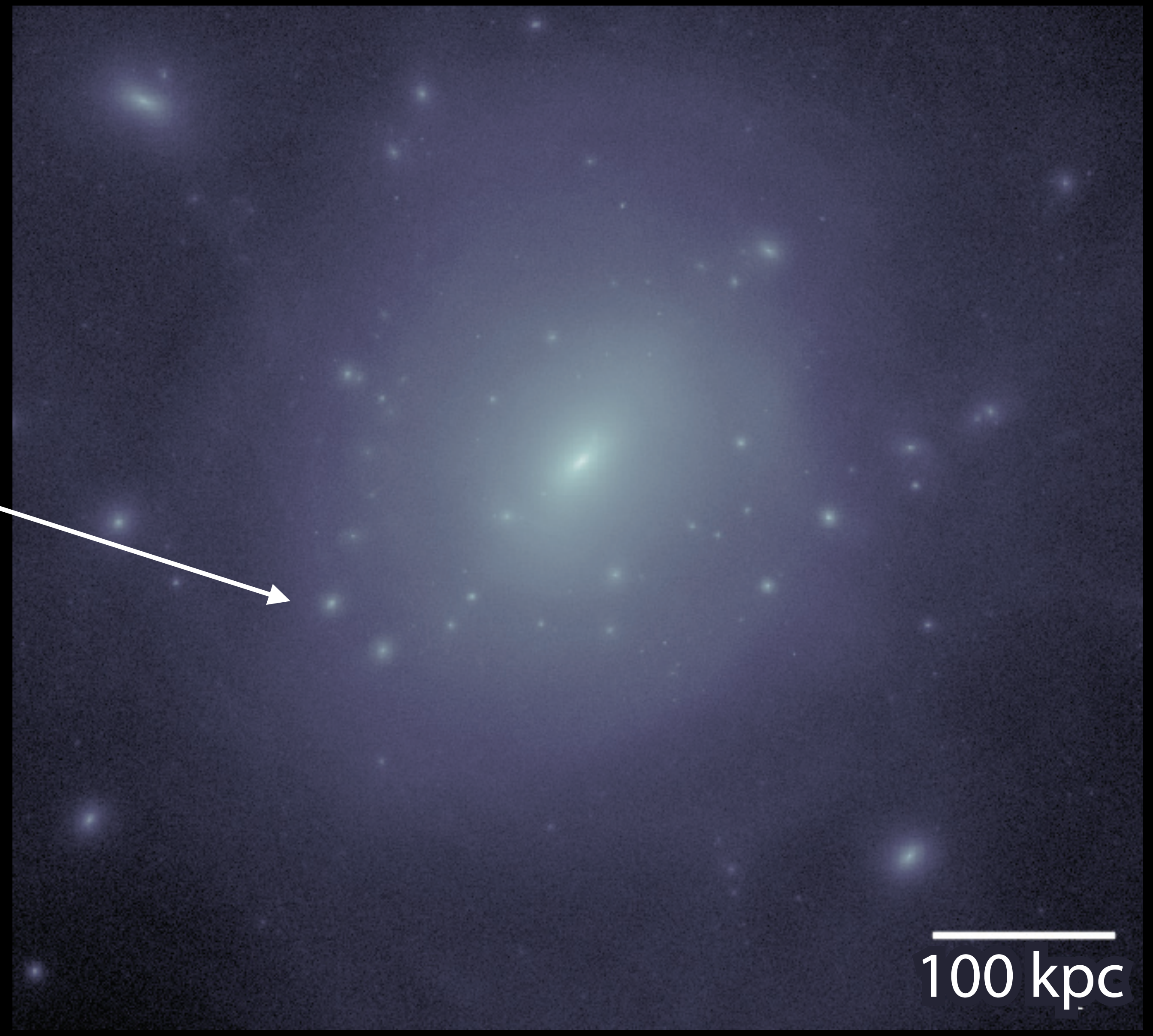
- can detect the smallest galactic satellites of nearby large galaxies by counting individual stars.
- can build a sample of 500-1000 of these "ultra-faint" satellites for cosmologically useful constraints on the DM particle mass.
- Hubble lacks the sensitivity and JWST lacks the optical-band resolution to perform these observations.



Cold Dark Matter = many satellites

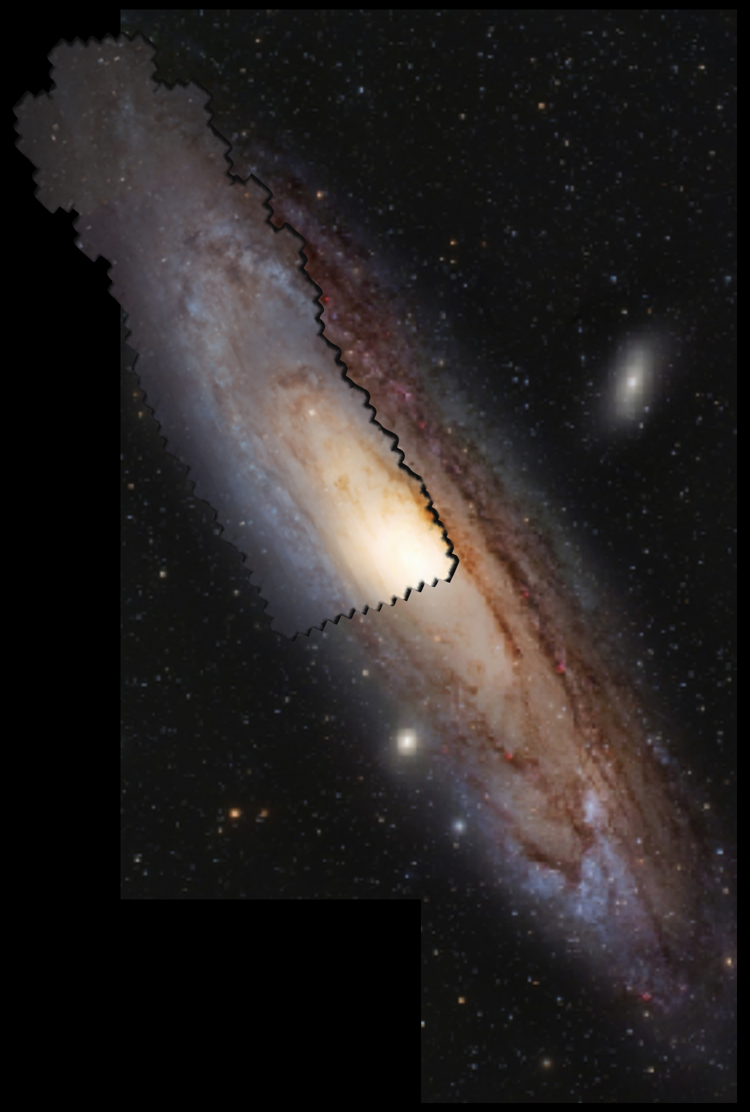


Warm Dark Matter = fewer satellites



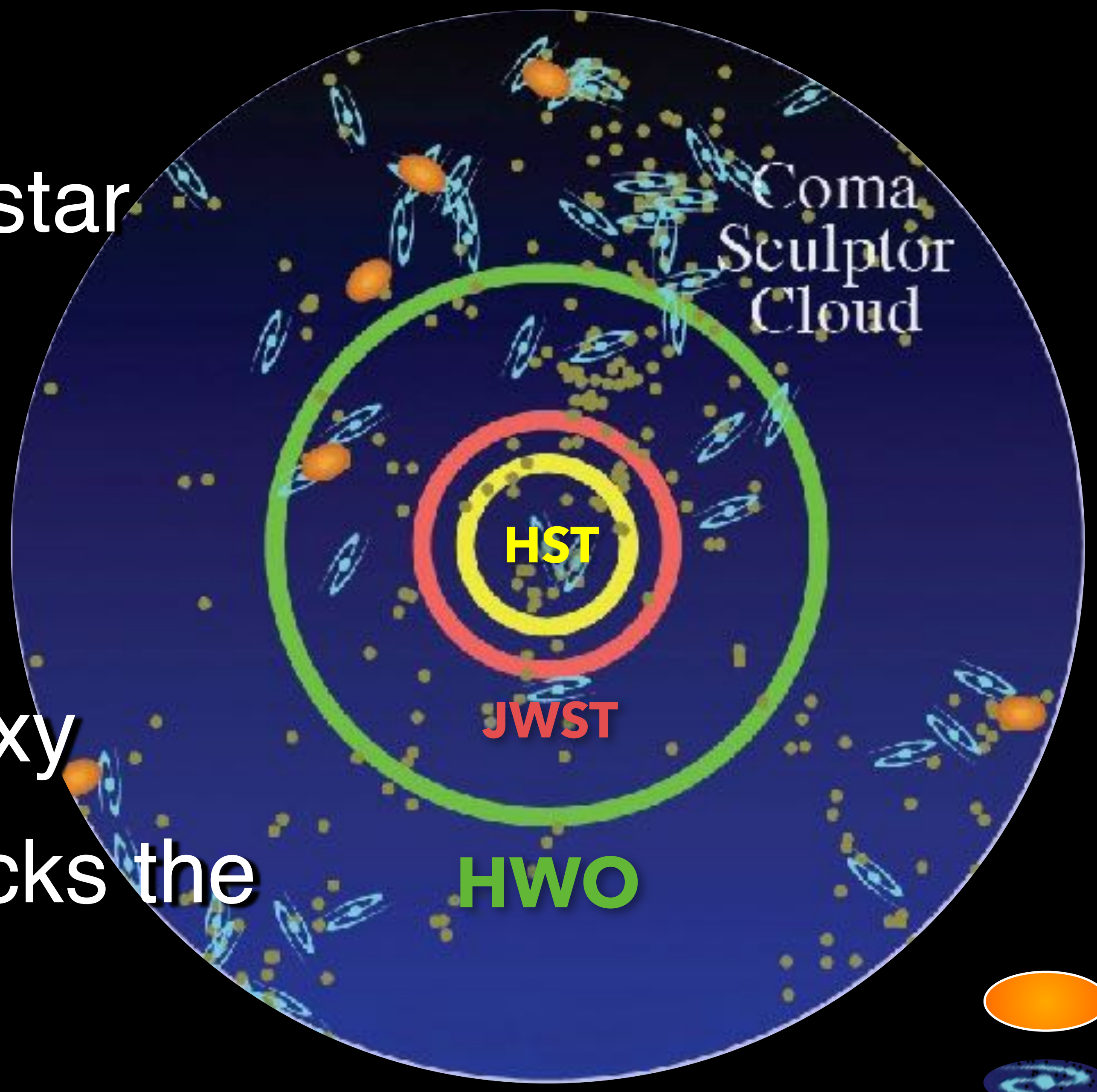
How does star formation propagate within

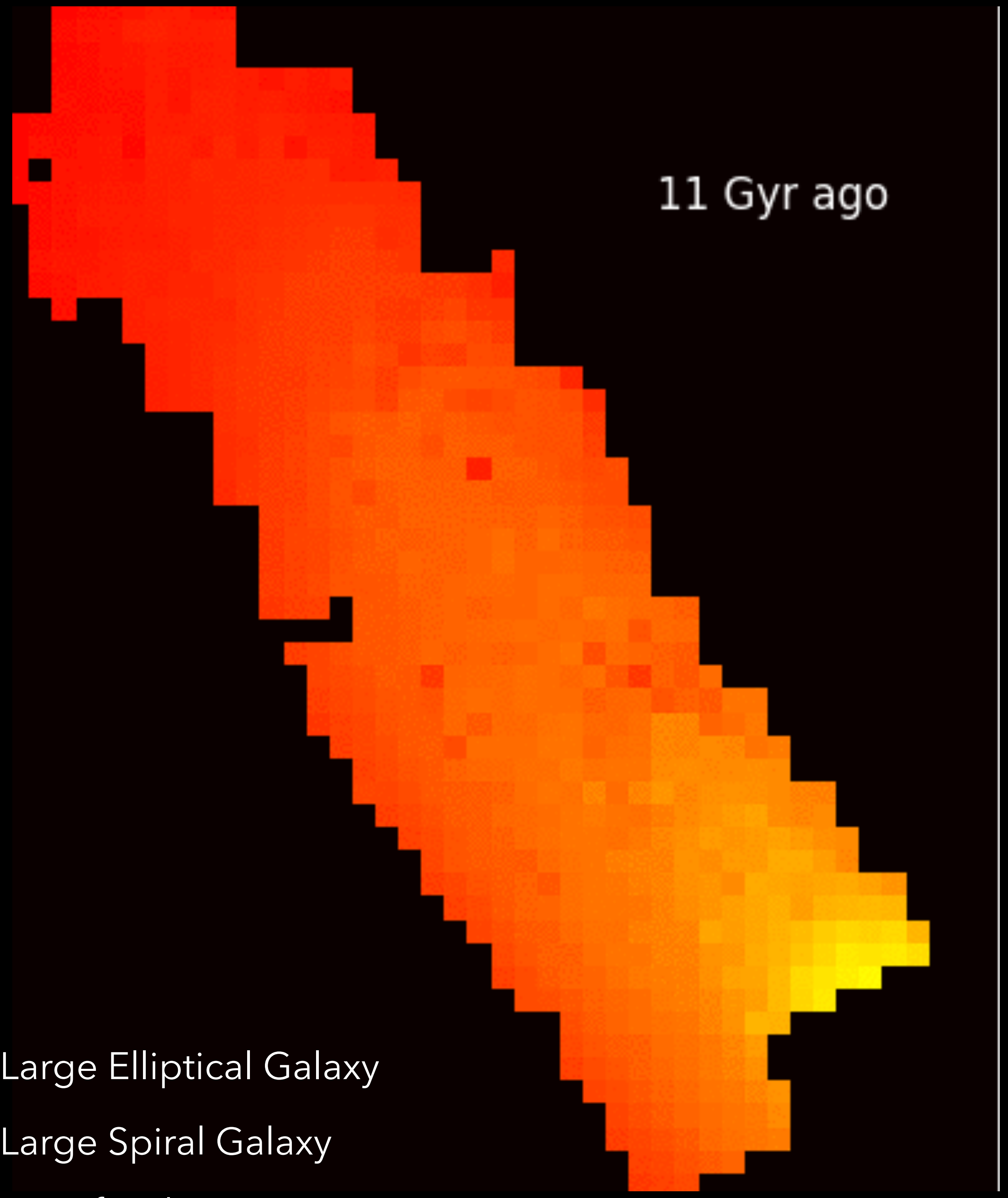
- normal galaxies assemble their disks over more than 10 billion years
- the remaining stellar populations can be read by astronomers to map the history of star formation in detail in a kind of “fossil record” going back 10 billion years.
- but, these maps must be resolved to see individual stars and



Only HWO:

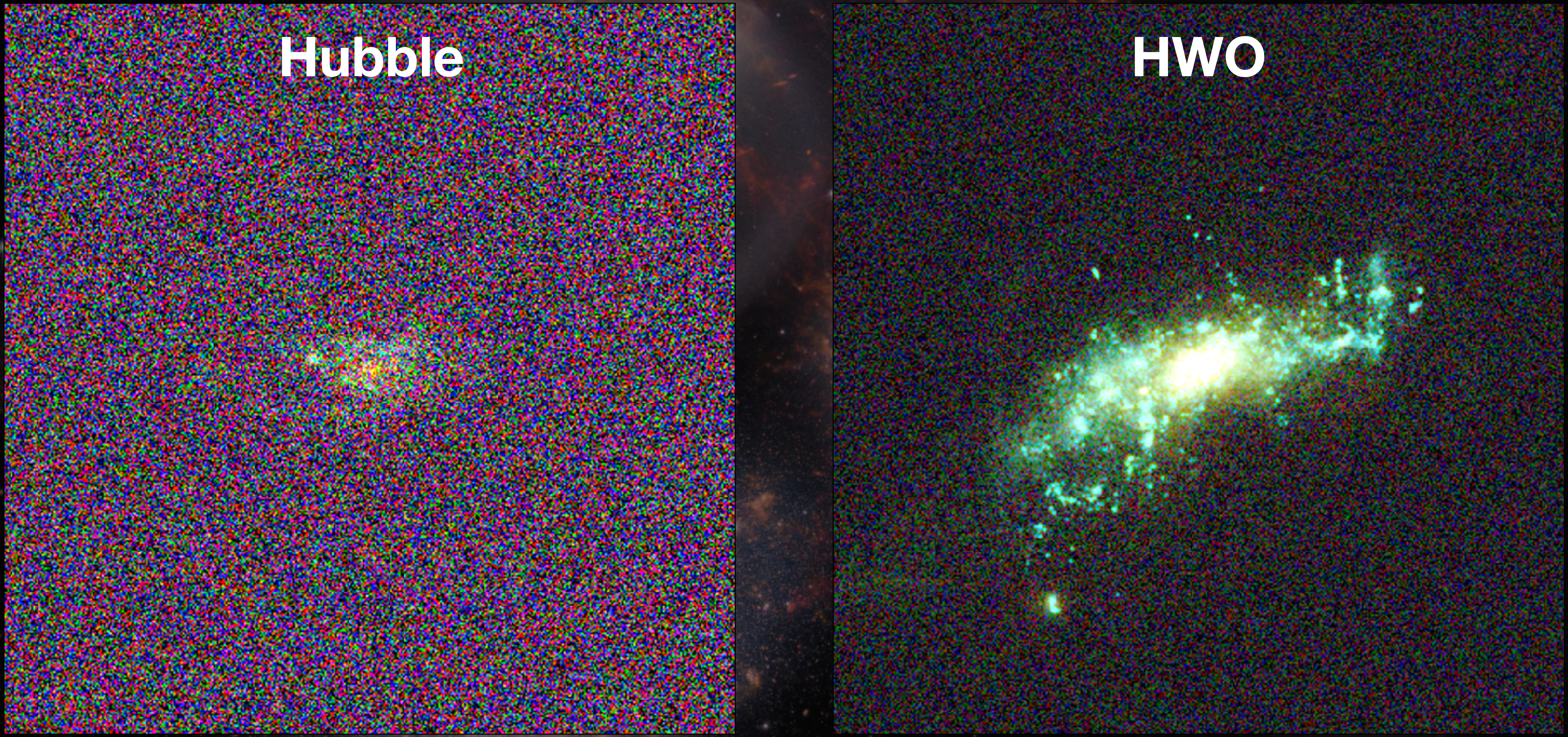
- has the resolution and sensitivity to map star formation
- in hundreds of local dwarf galaxies.
- can map spirals beyond Andromeda
- can reach the nearest giant elliptical galaxy
- Hubble lacks the sensitivity and JWST lacks the optical-band resolution to perform these observations.





Seeing the smallest building blocks of galaxies

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



Preliminary simulation

Credit: Postman, Snyder (STScI)

Seeing the smallest building blocks of galaxies

To understand the formation of the Milky Way, we must reach the minimum mass scale and spatial resolution for the smallest galaxies

HABITABLE WORLDS OBSERVATORY

Transformative Astrophysics Capabilities

deep fields mapped 8x faster than Hubble and 4x JWST

1.4 million individual shutters for intensive UV spectroscopy

precise proper motions from sub-microarcsecond astrometry

mapping the baryon cycle in emission and absorption

reliable photometry in fields 50x denser than Hubble

resolving the outer solar system as well as in-situ spacecraft

seeing all the building blocks of galaxies

29th magnitude point sources in an hour

Your idea here!

servicing to achieve leaps in instrument capabilities


Astronomy shows us we are a small part of a vast cosmos.
you are here
Let’s remember our cosmic origins


you are here

Earth teems with life. . .





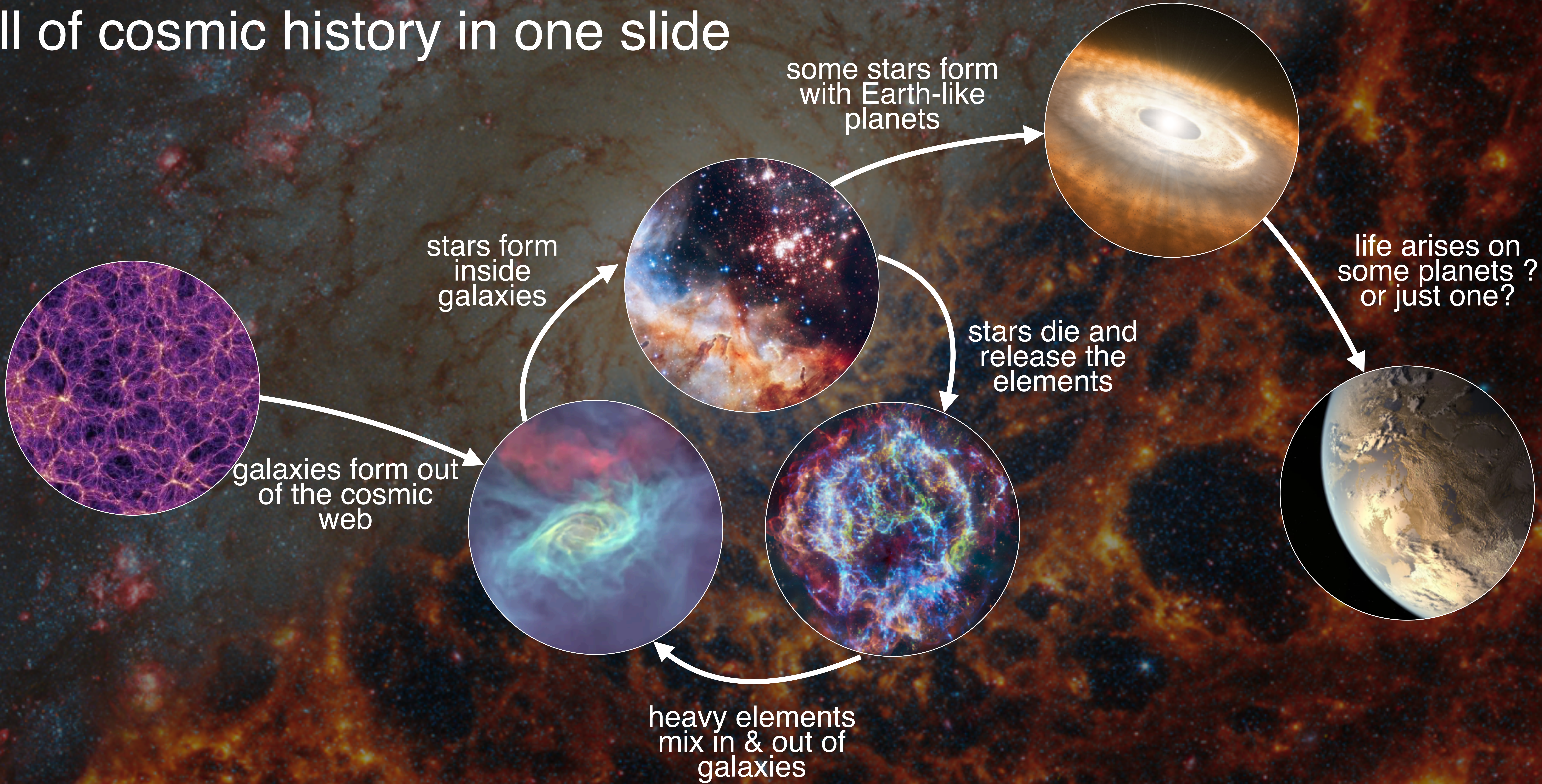
Where did it all come from?

thanks to biology, we know we share kinship with all life on Earth . . .

. . . but has Nature repeated this experiment elsewhere in the Cosmos?

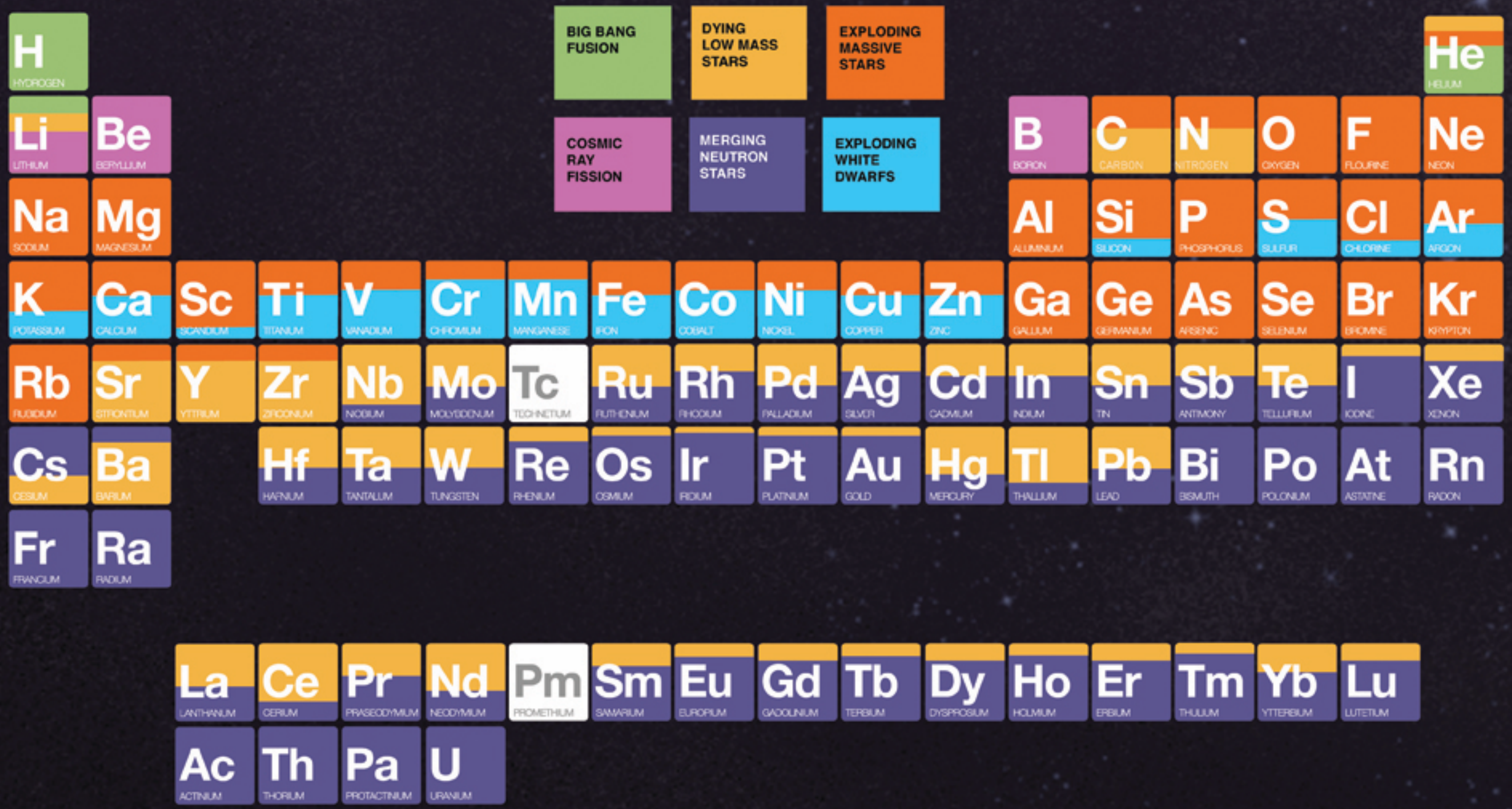
let’s review . . .

all of cosmic history in one slide



The Tree Of Life is rooted in the stars. . .

. . . because stars create the elements . . .



https://chandra.harvard.edu/photo/2017/casa_life/

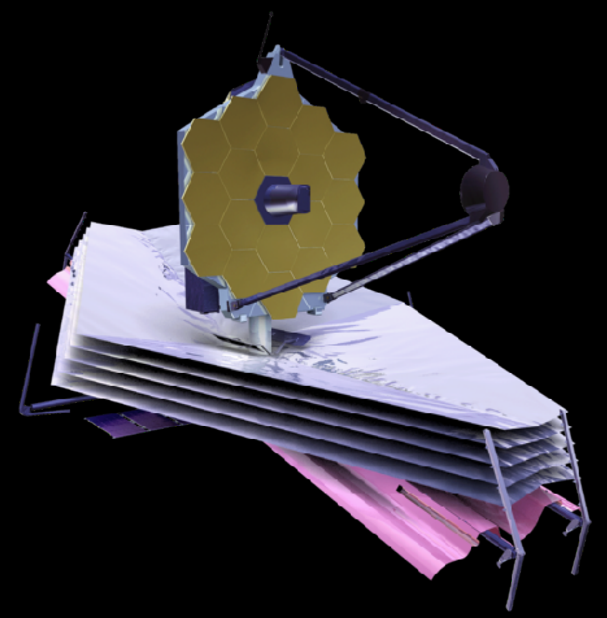

. . . so that . . .
You Were Here
in the remains of an exploded star. . .


And here!
in the stellar nursery that formed the Sun . . .


You Were Here Too
in the Milky Way’s CGM, before gravity brought you back in!


if HWO can
find Earth-
like planets
then we can say
WE are here
Venus
Earth
and find signs of
life in their air
. . . and HWO will show us the cosmic
history we share with this other life!

Vision, Teamwork, Optimism & Patience: The Elements of Success



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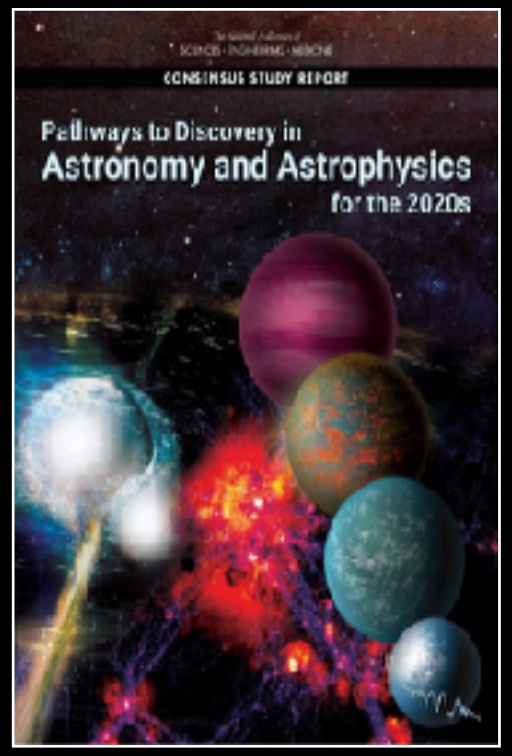
2021



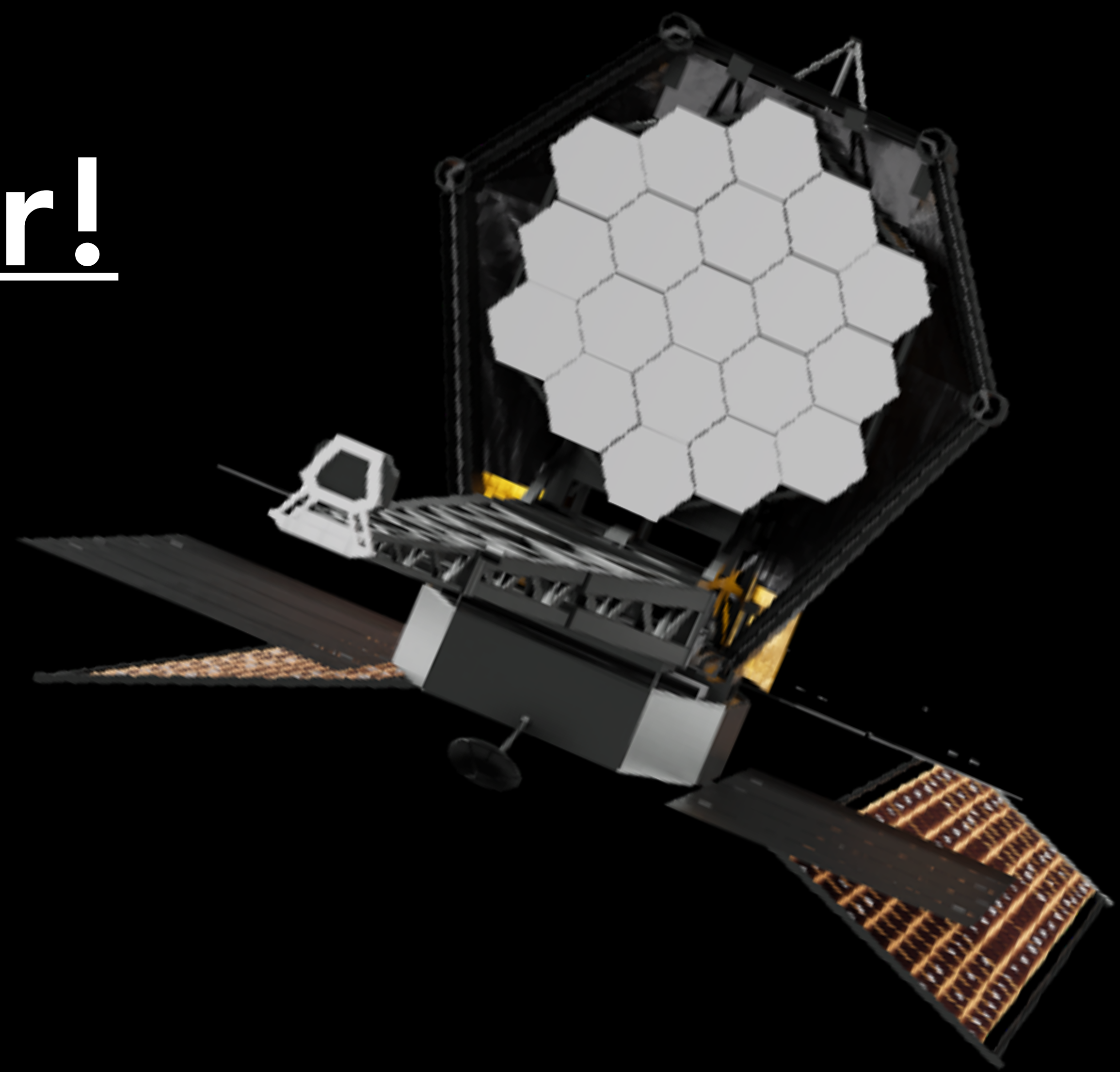
2025

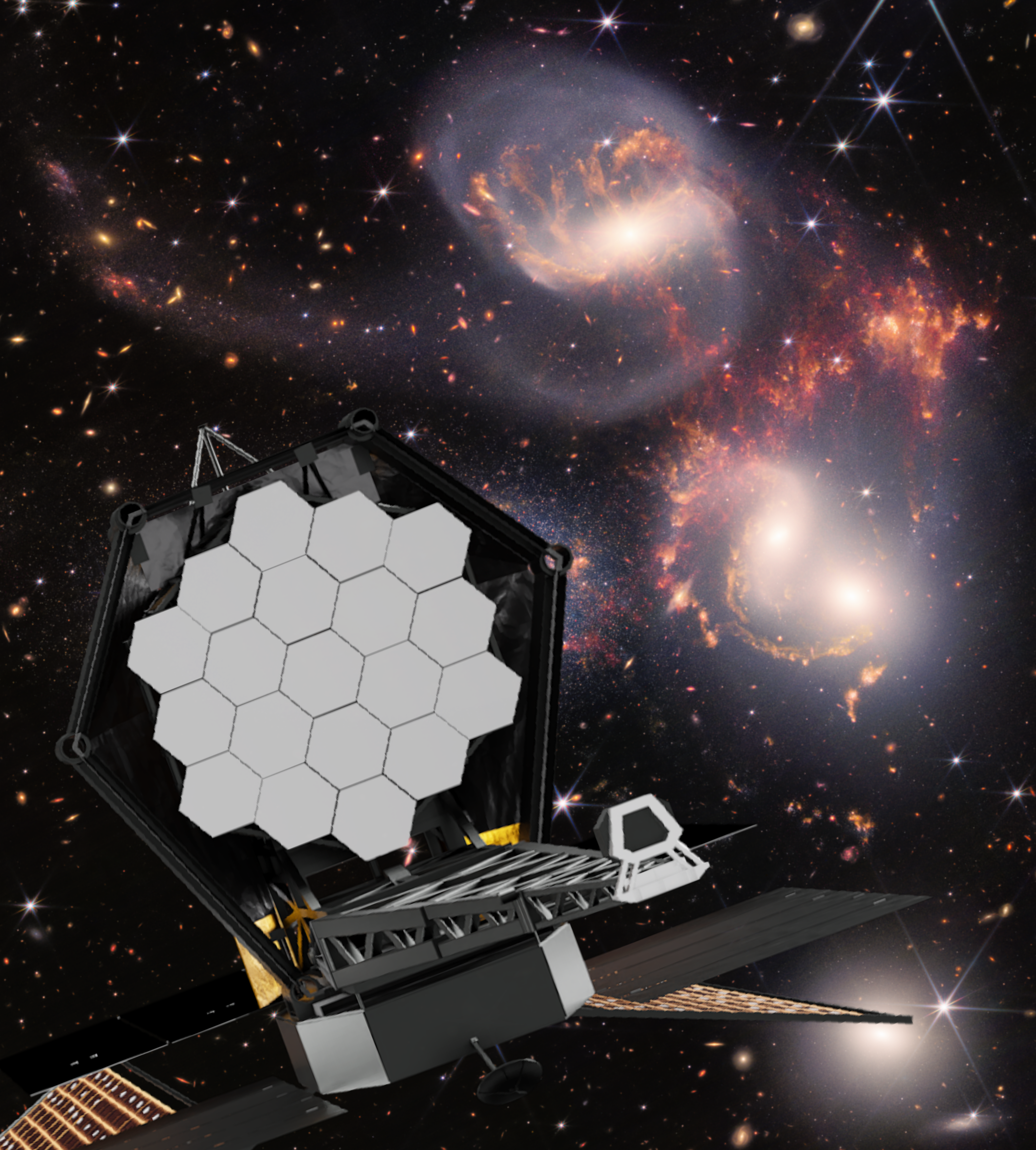
Yardstick Designs, Compelling Storytelling, Building International Collaborations

We are here

2035+

<u>Let's do this part together!</u>





graze mille!

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