Introduction to Habitable Worlds Observatory

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A Future Space Mission with Very High Precision Astrometry Workshop

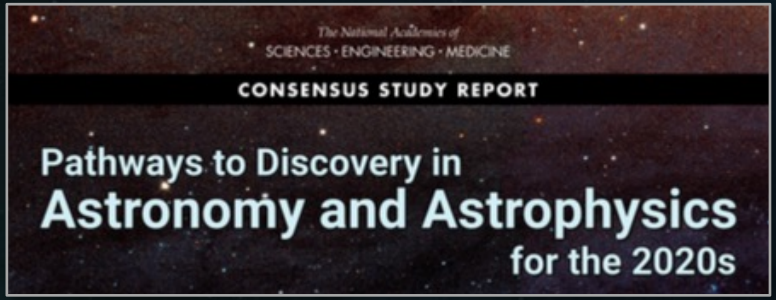
Institut d'Astrophysique de Paris

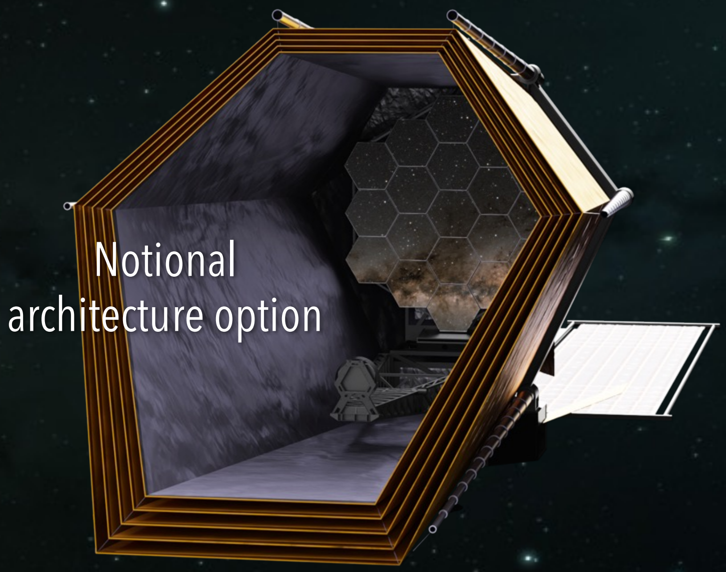
Sept 12, 2024

HABITABLE WORLDS OBSERVATORY

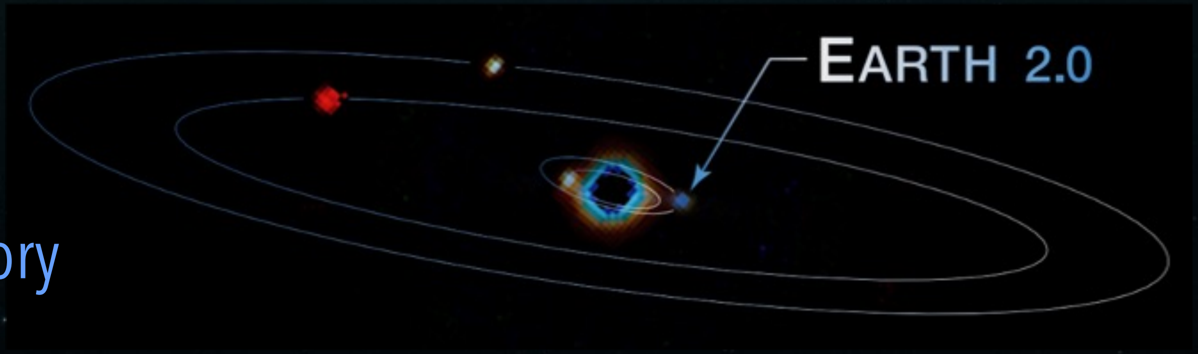
What is Habitable Worlds Observatory (HWO)?

NASA's next flagship mission concept recommended by Astro2020 Decadal Survey





First telescope designed to search for signs of life on planets outside our solar system



Large-aperture UV / Optical / NIR space observatory performing transformative astrophysics

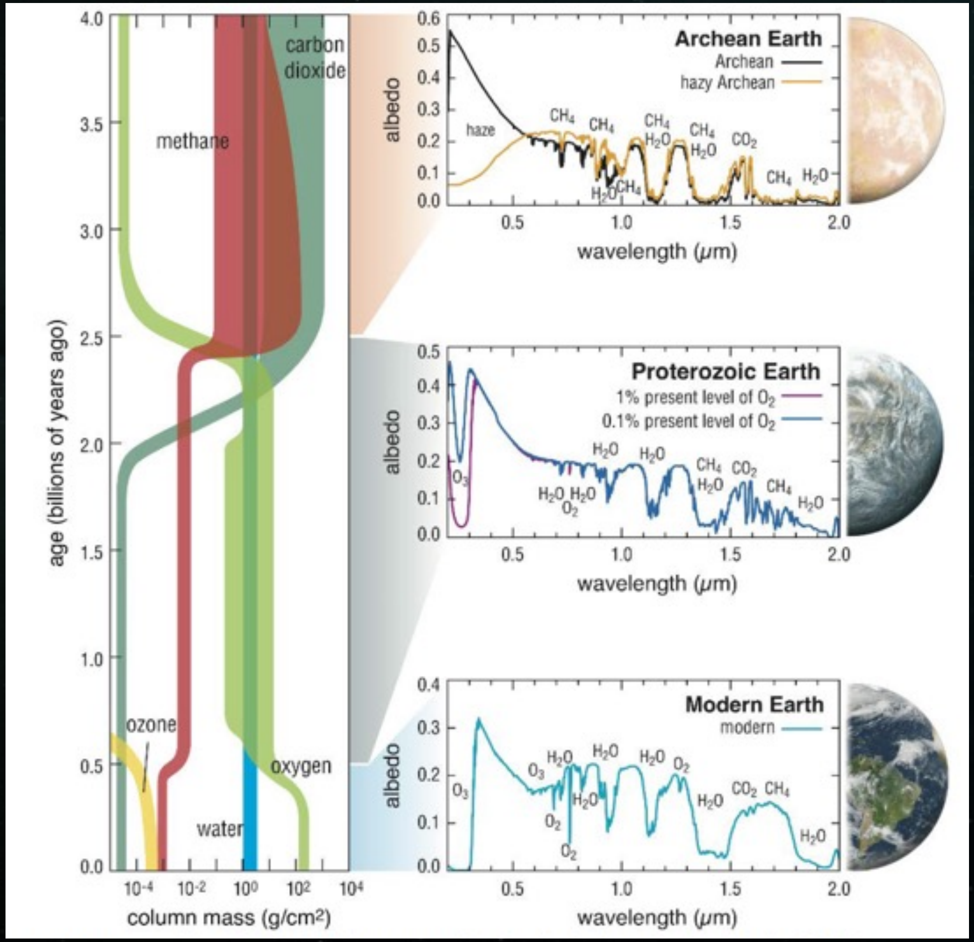
"If planets like Earth are rare, our own world becomes even more precious.

If we do discover the signature of life in another planetary system, it will change our place in the universe in a way not seen since the days of Copernicus."

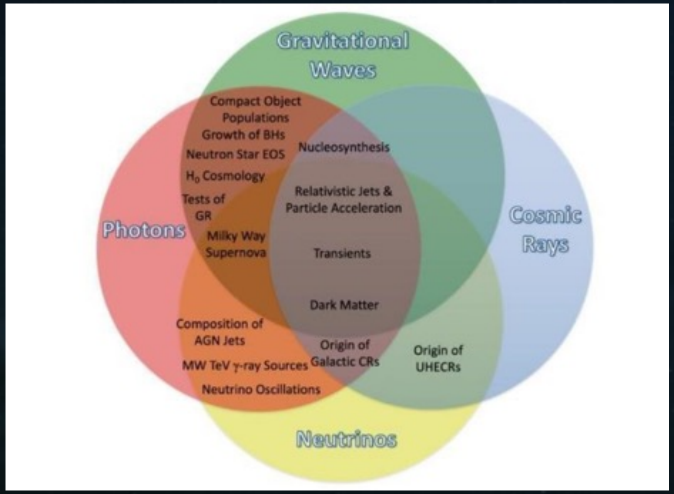
National Academies of Sciences, Engineering, and Medicine Astro2020 Decadal Survey Report (Nov 2021)

Astro2020 Science Themes

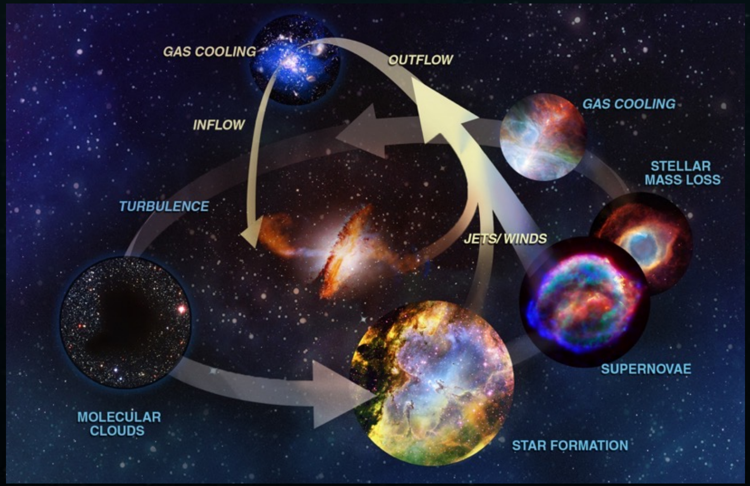
Worlds and Suns in Context: Pathways to Habitable Planets



New Messengers & New Physics: New Windows on the Dynamic Universe



Cosmic Ecosystems: Unveiling the Drivers of Galaxy Growth



Astro2020 Science Themes

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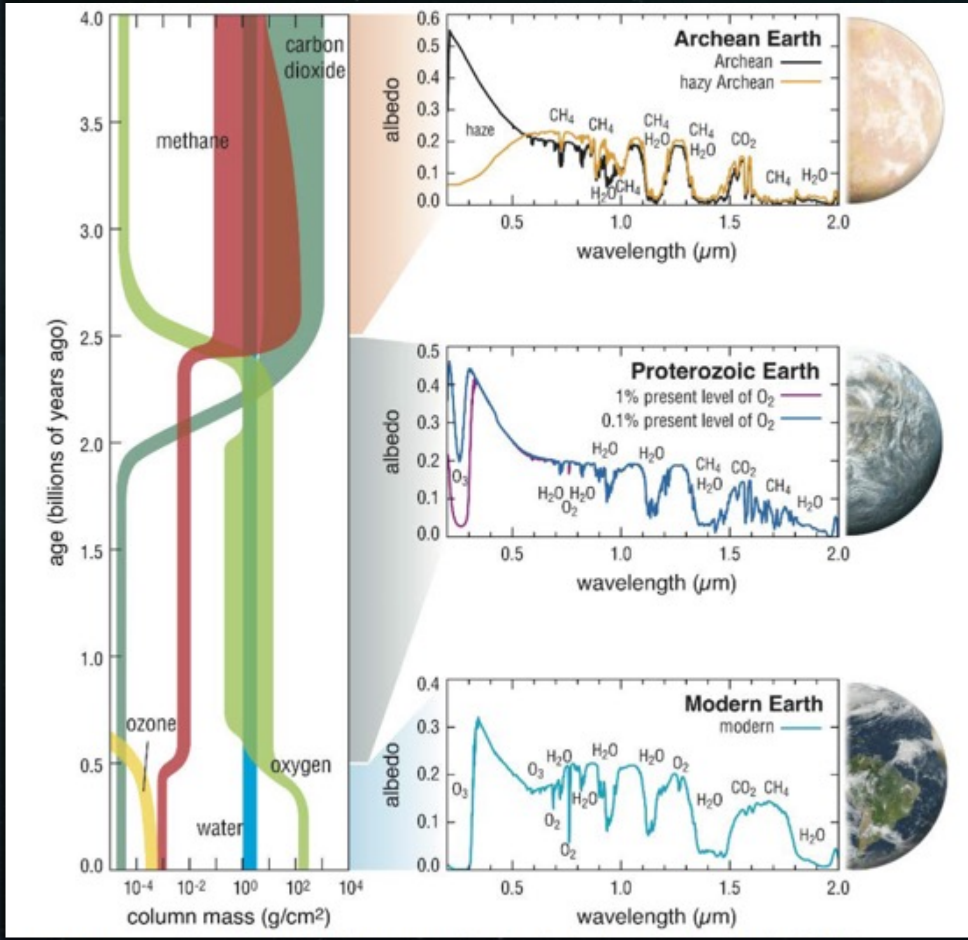

Habitable Worlds Observatory

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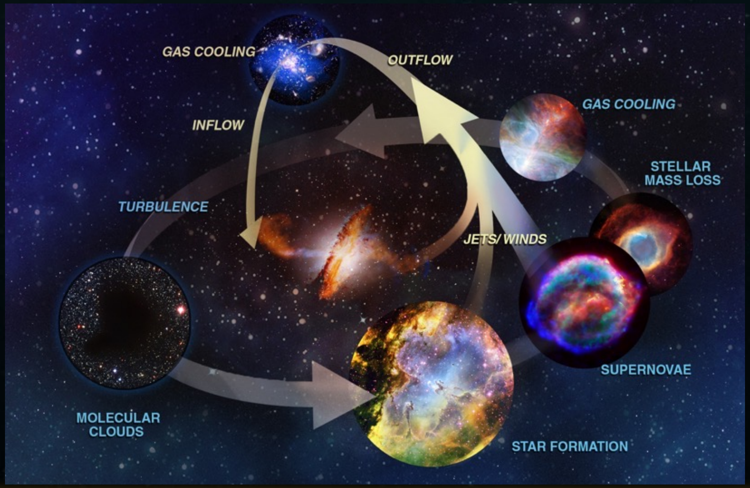

Astro2020 Science Themes

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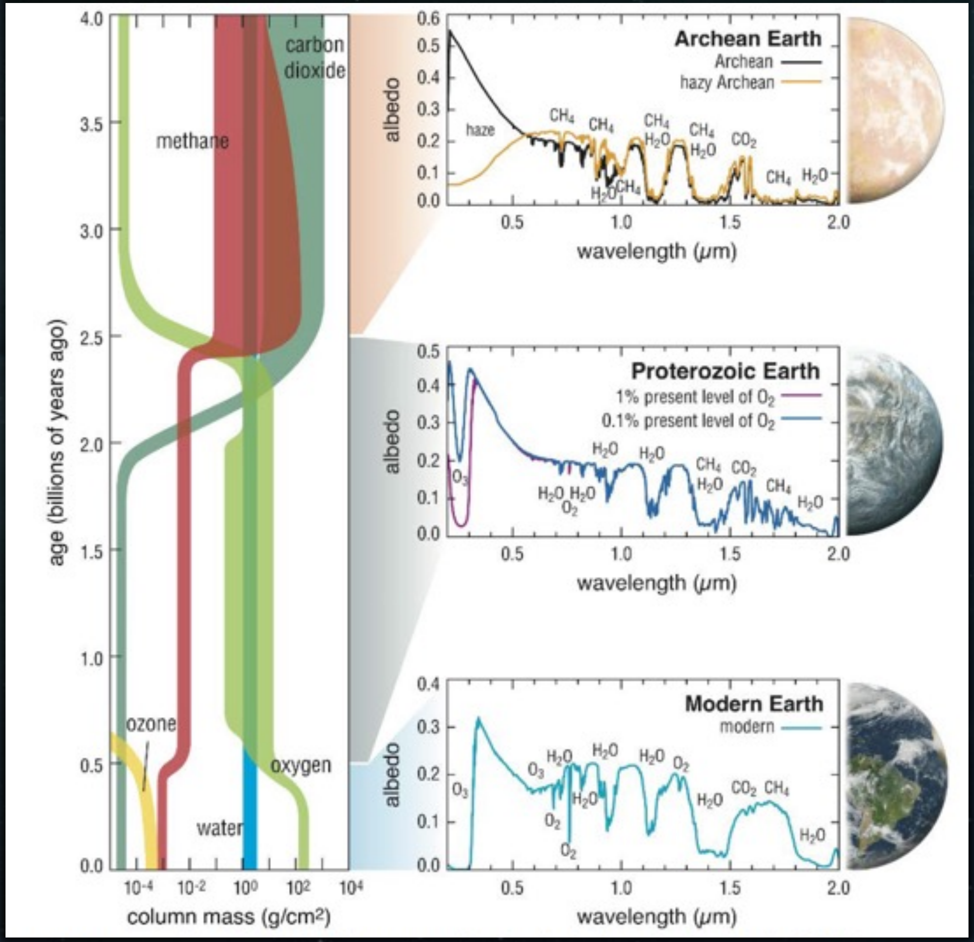
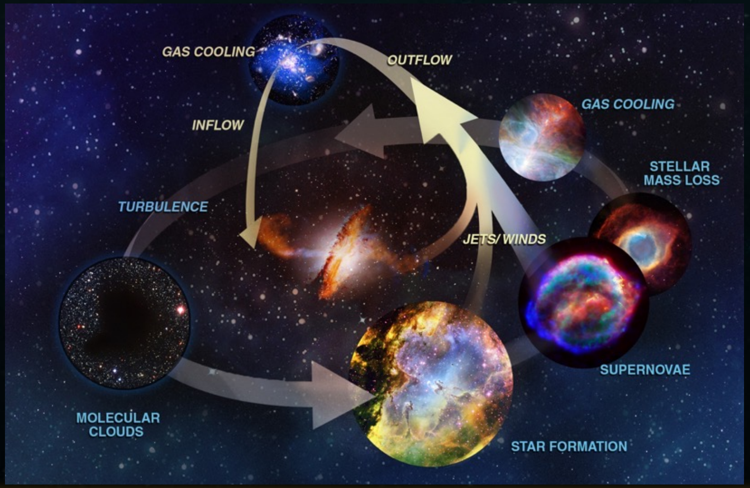


New Messengers & New Physics: New Windows on the Dynamic Universe

Dark Matter?

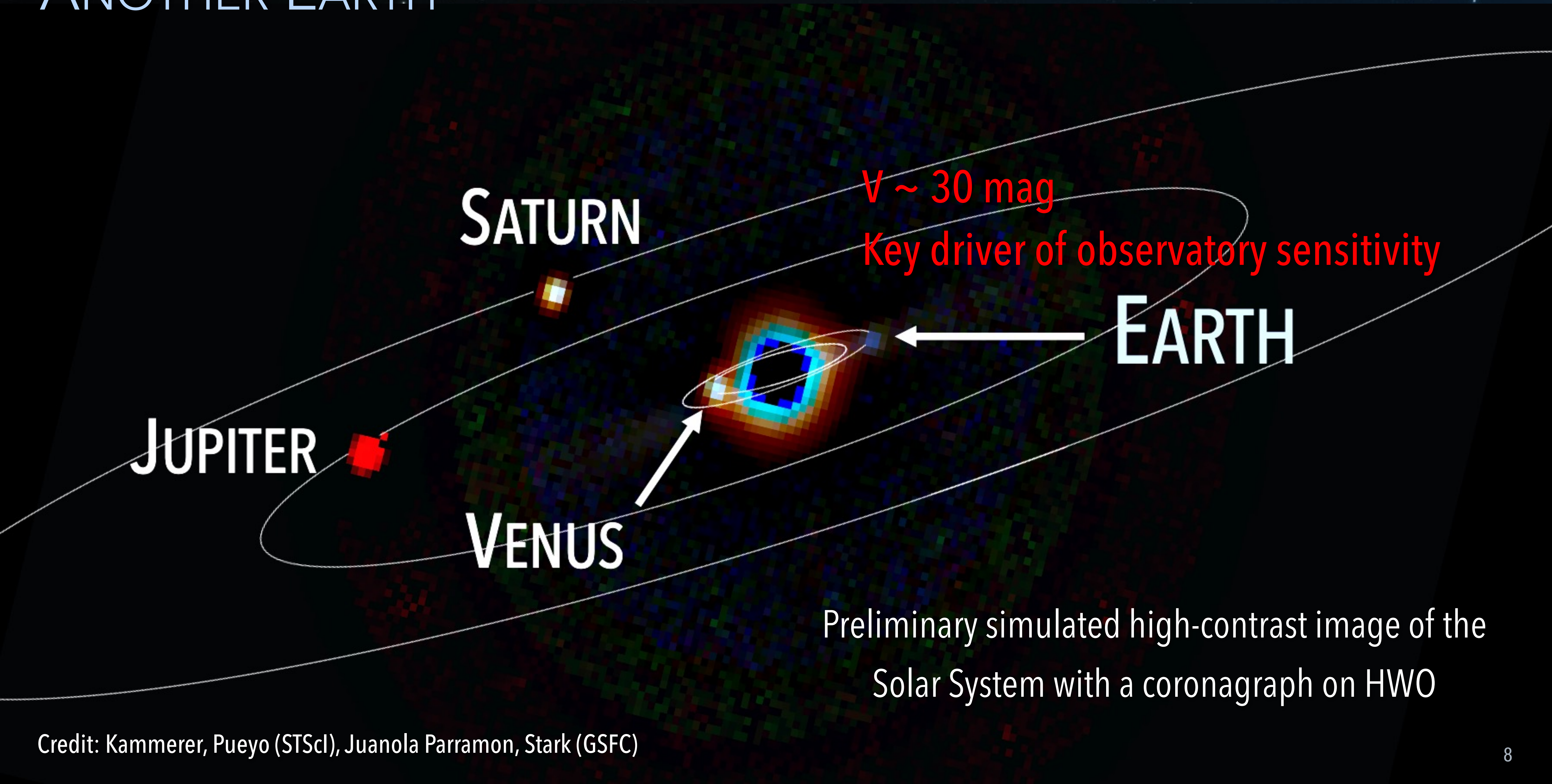
Habitable Worlds Observatory

Cosmic Ecosystems: Unveiling the Drivers of Galaxy Growth



Habitable Worlds Observatory Science

Another Earth



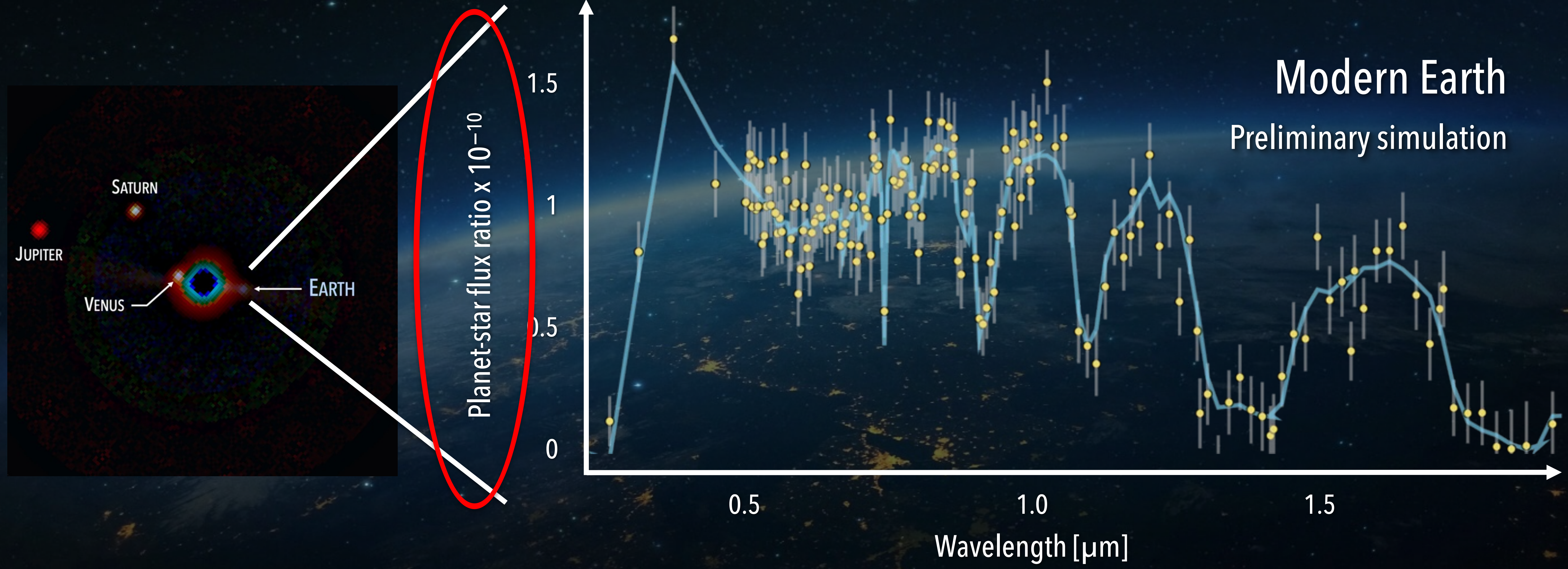
Preliminary simulated high-contrast image of the Solar System with a coronagraph on HWO

Credit: Kammerer, Pueyo (STScI), Juanola Parramon, Stark (GSFC)

Searching for Global Biospheres

Credit: Lustig-Yaeger (JHU-APL), Robinson (NAU), Arney (GSFC)

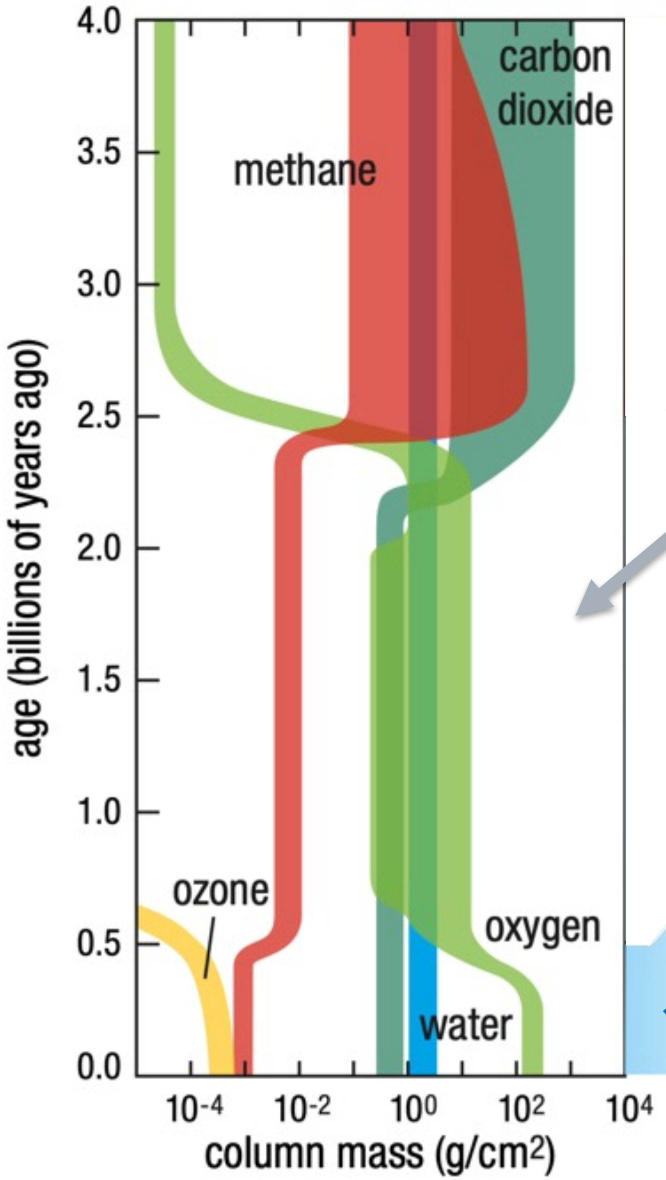
Key driver of telescope stability



Analyze light directly reflected by the planet, with little or no starlight mixed in

EARTH IS MORE THAN ONE PLANET

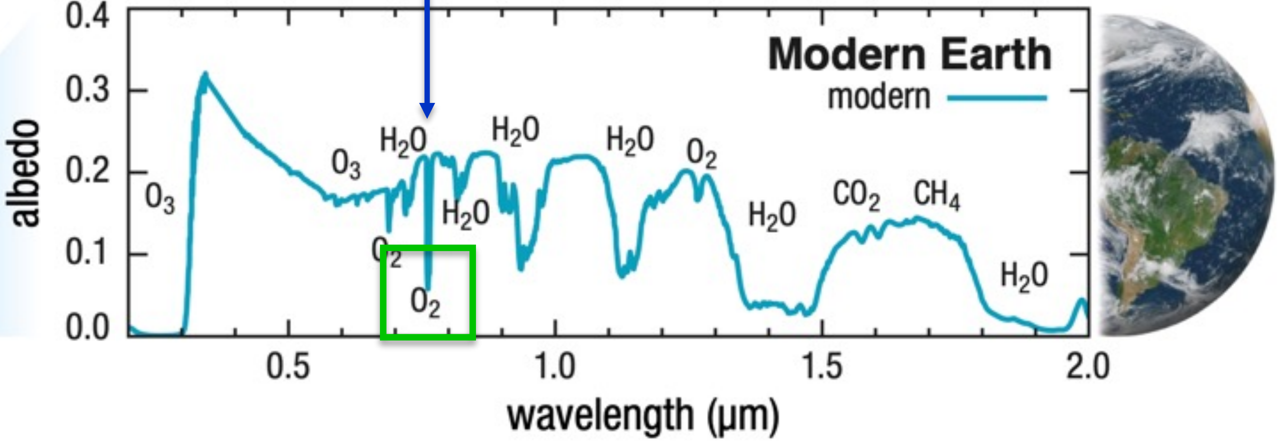
Credit: LUVOIR & HabEx Final Reports
Arney, Domagal-Goldman, Griswold (GSFC)



Earth's atmospheric composition through time

Key driver of spectral resolution

13%



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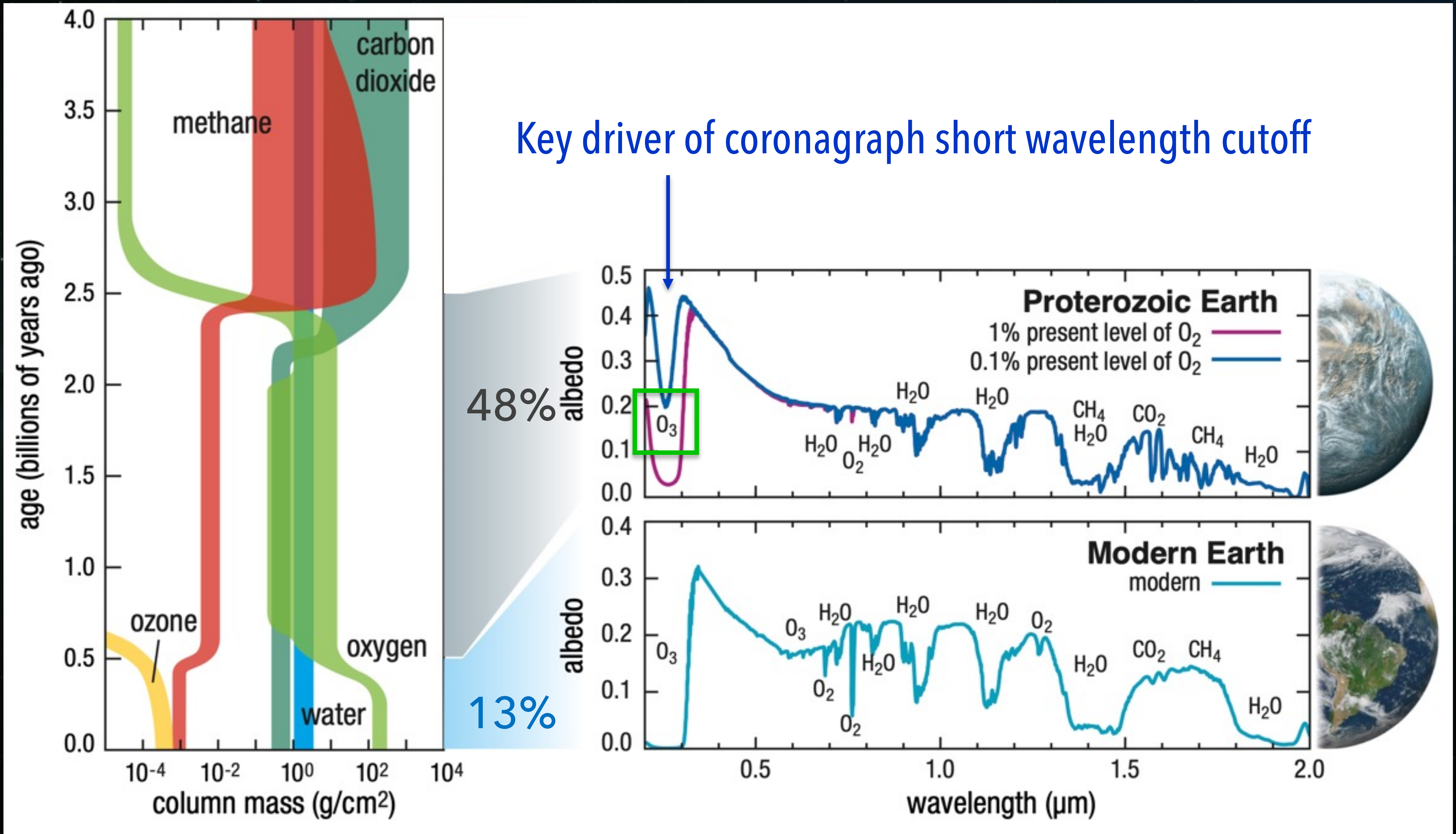
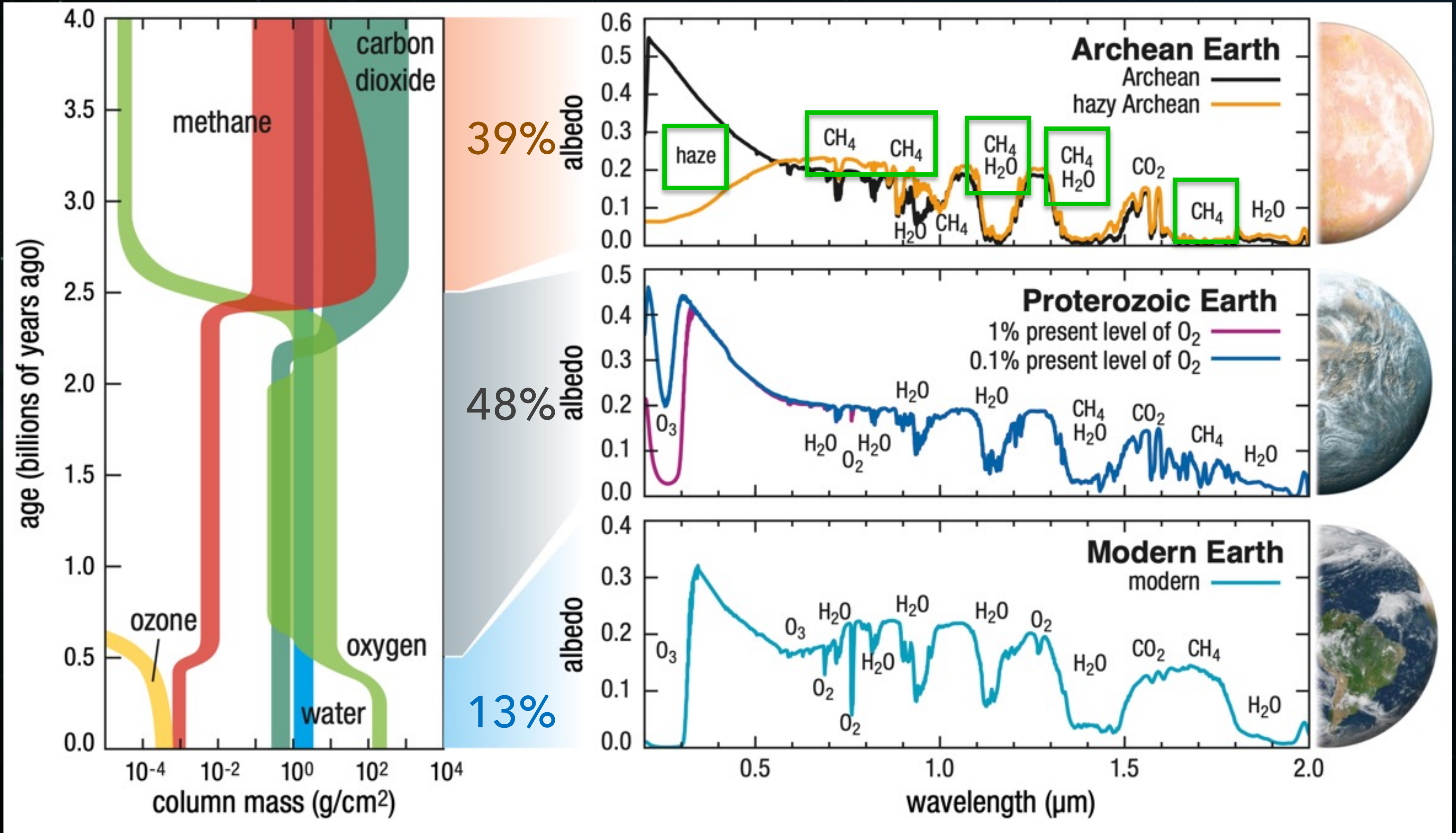


Earth is more than one planet



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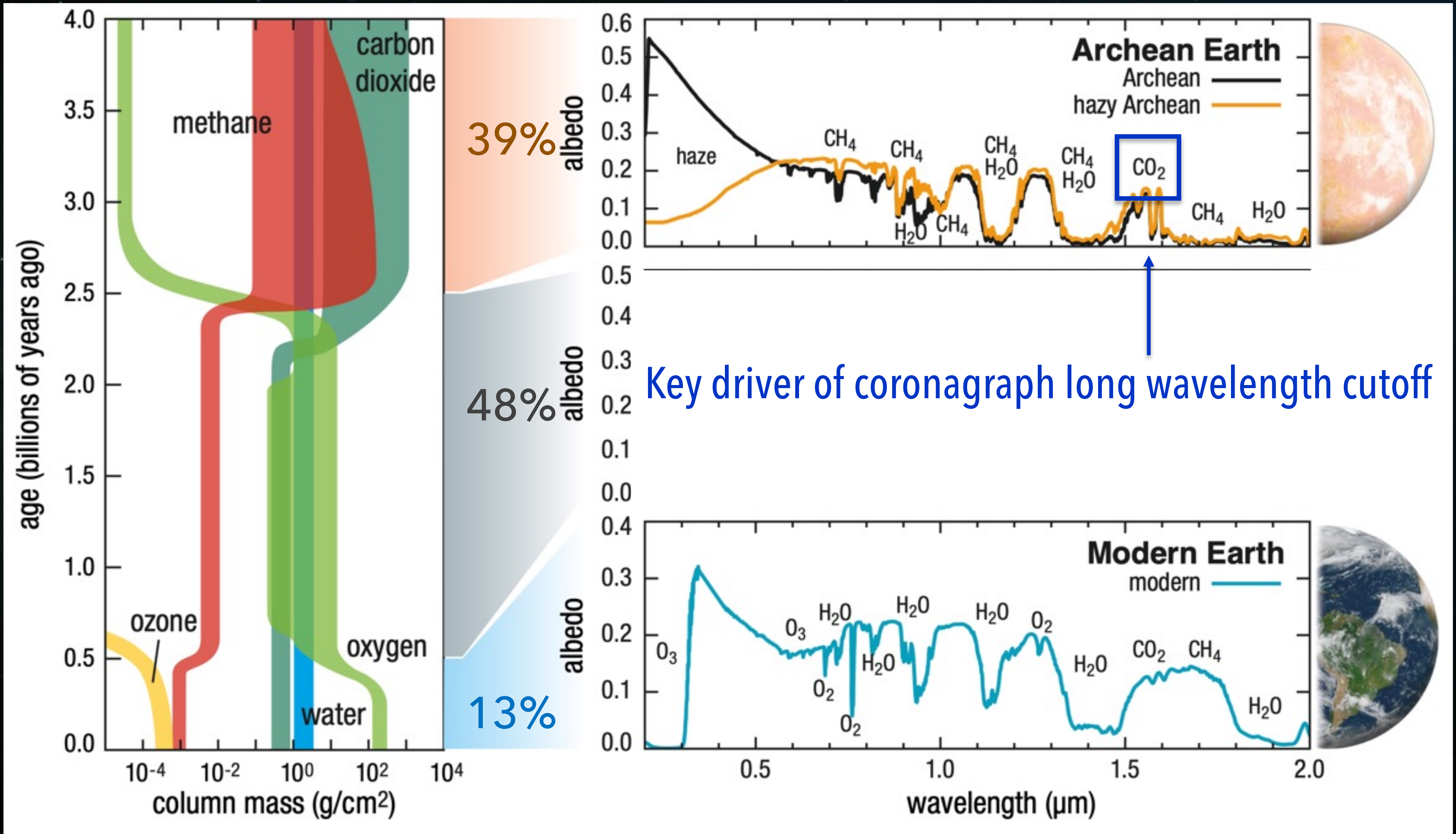
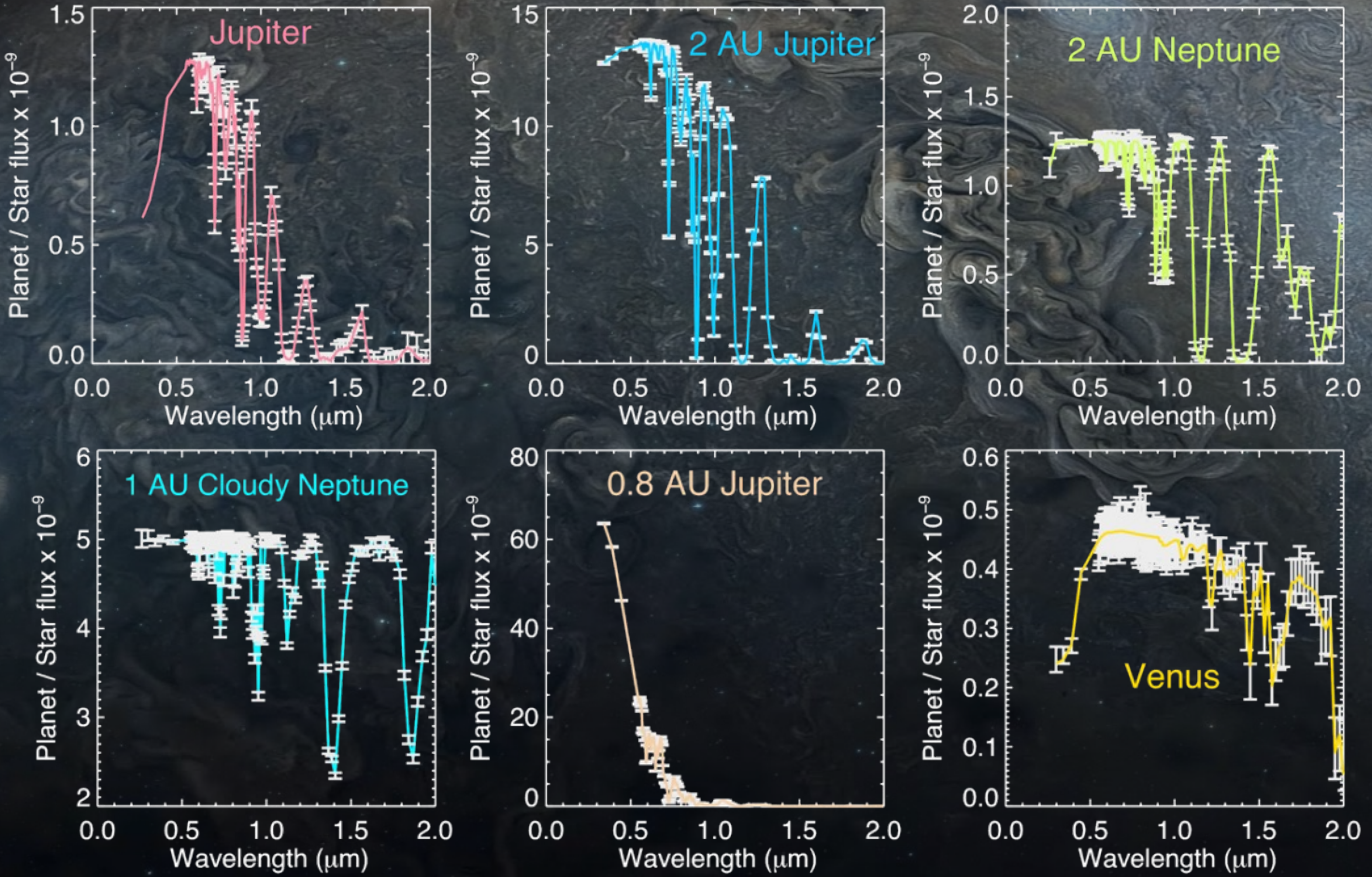


Comparative planetology

Credit: Arney, Roberge (GSFC)



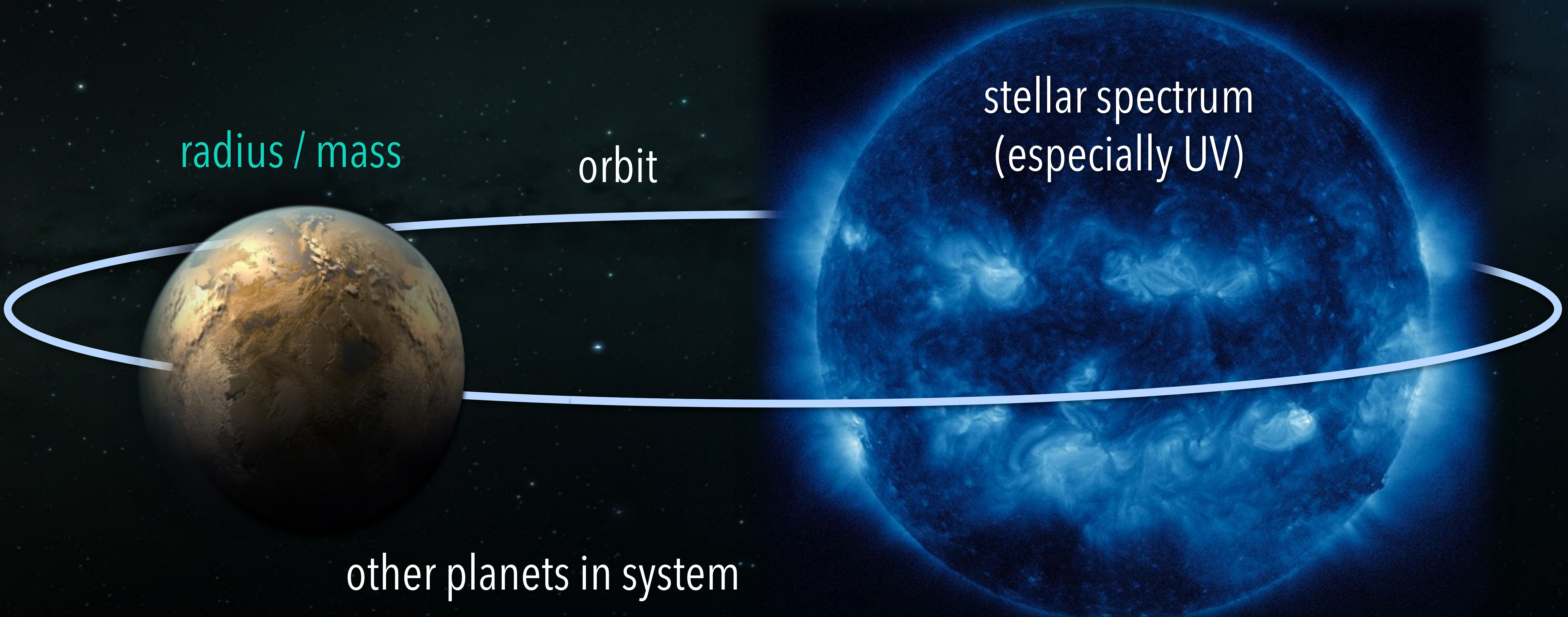
Preliminary simulations

Hundreds of other types of exoplanets found during a habitable planet survey

Direct & transit spectroscopy both possible

Interpreting a planet

To understand the planet, we need a lot of information beyond its spectrum



How do we get planet radius / mass?

Radius

Cannot be directly measured for non-transiting planets

Possibly can be inferred from pressure-sensitive features in some planet spectra

Mass

Limits of extreme precision radial velocity from the ground unknown

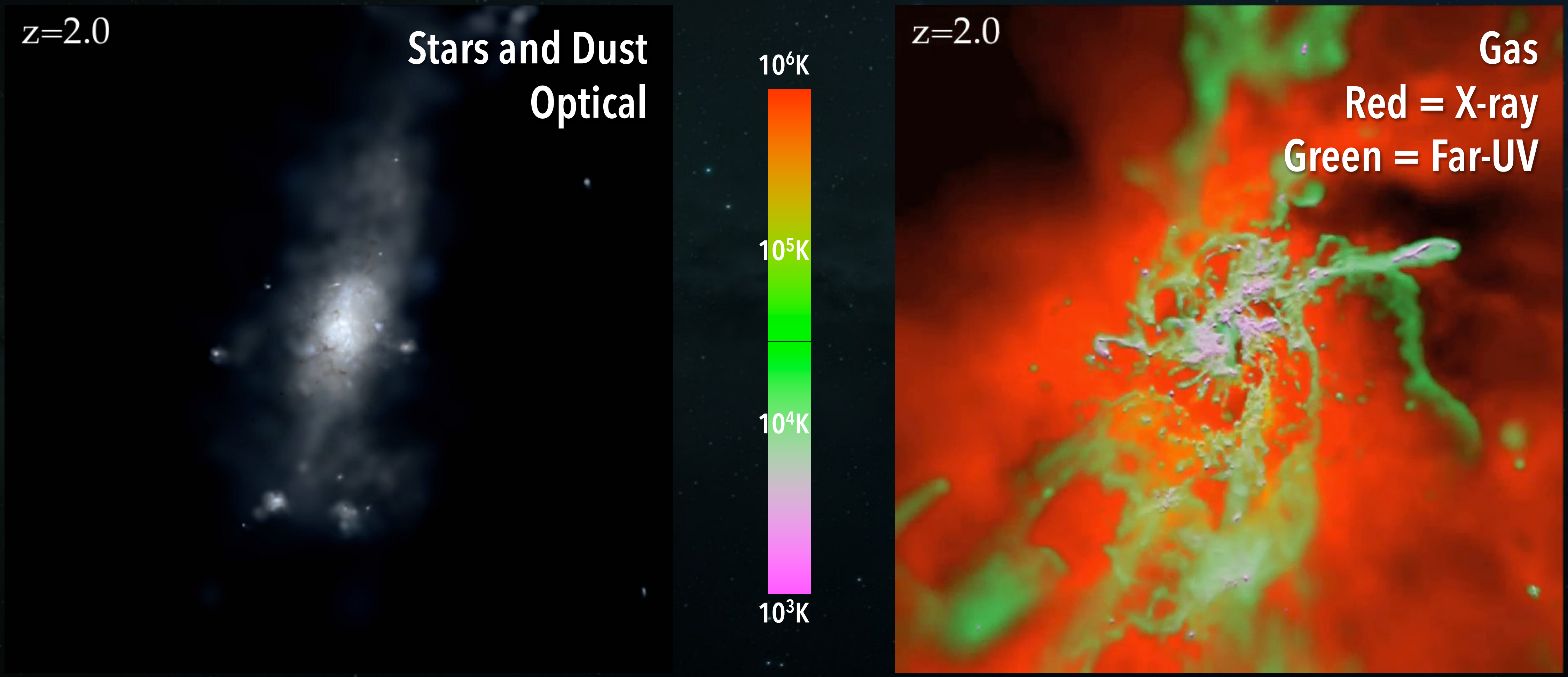
Not all HWO target stars will have low levels of stellar activity

For Earth-mass planets around FGK stars, space-based astrometry might be only option

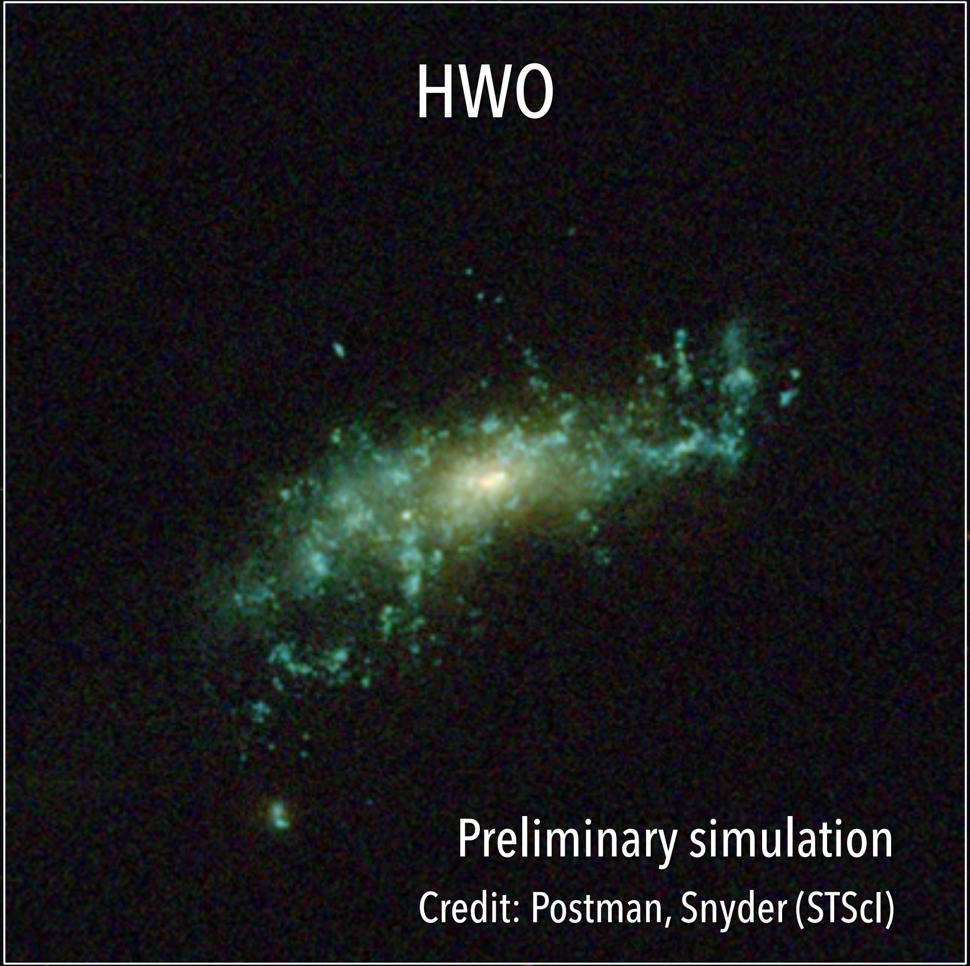
THE CYCLES OF MATTER

Illustris simulation

Credit: Snyder (STScI)

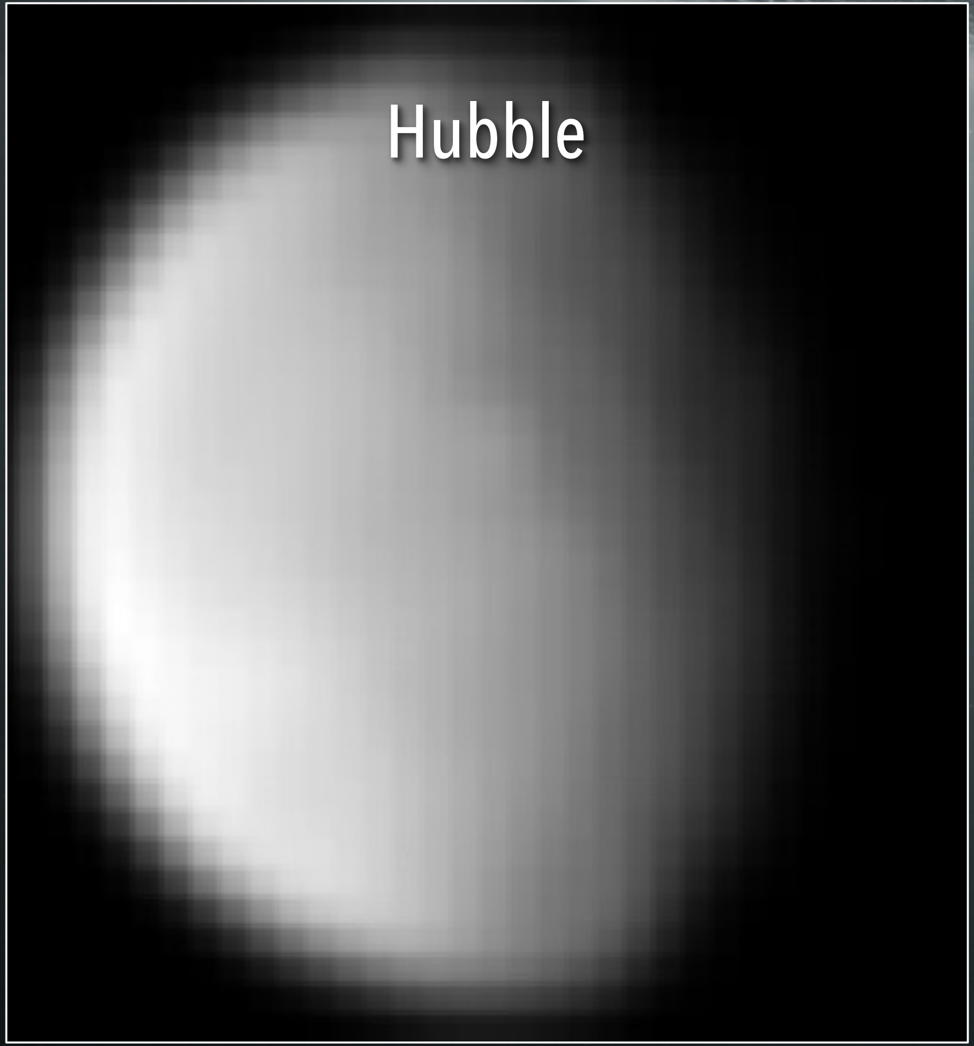


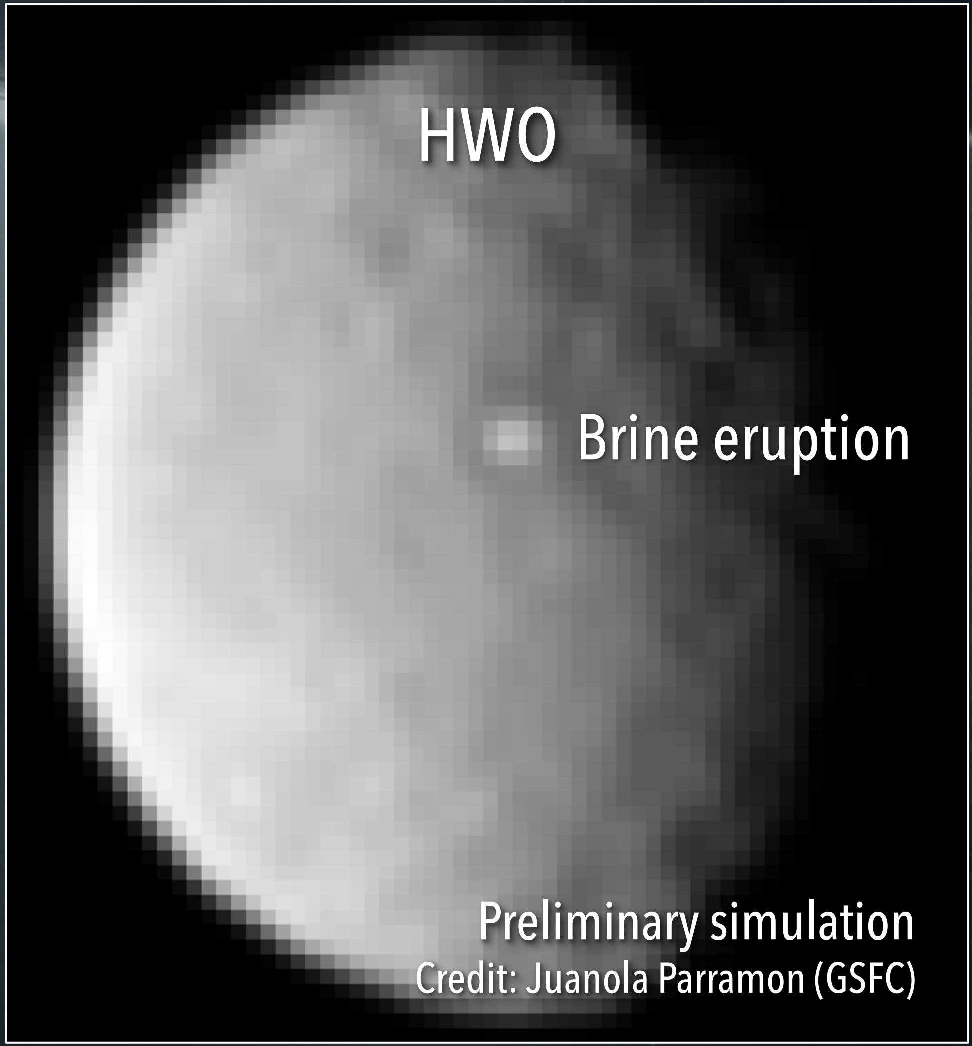
The building blocks of galaxies



Low-mass dwarf galaxy at redshift = 2

Monitoring our dynamic Solar System – Ceres

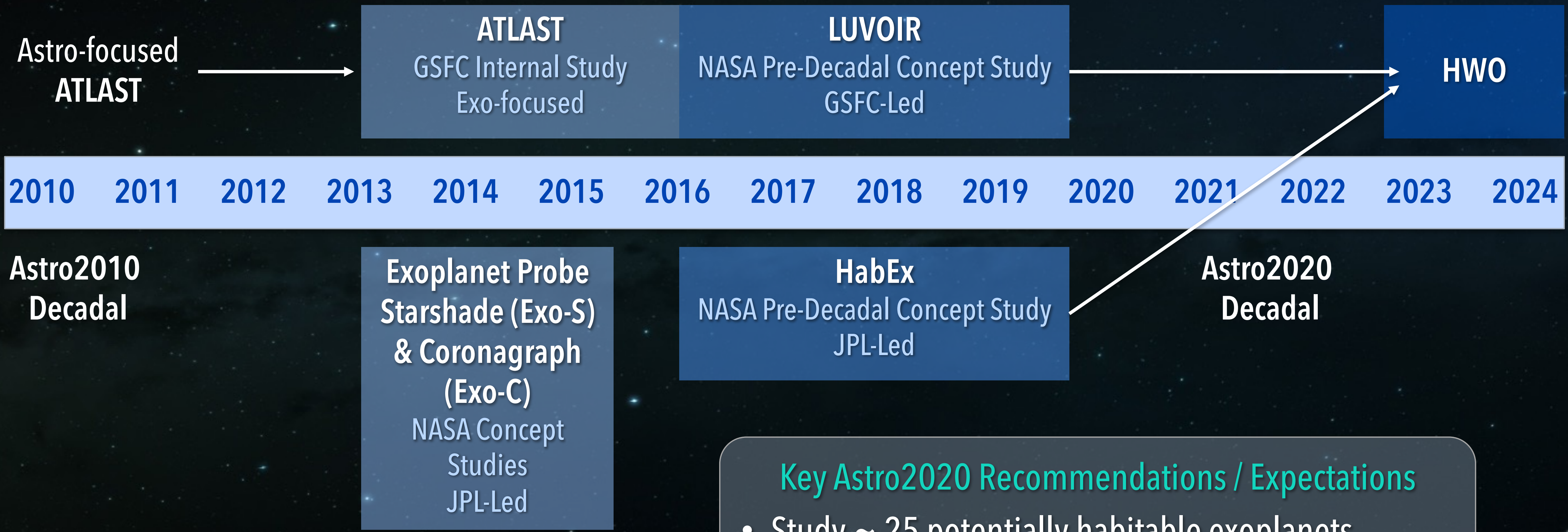




HWO Past, Present, and Future

June 2024 HWO Team Meeting
Baltimore, MD

Habitable Worlds Observatory History



Key Astro2020 Recommendations / Expectations

- Study ~ 25 potentially habitable exoplanets
- Enter Phase A this decade (aka. before Astro2030)
- Launch first half of 2040s

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

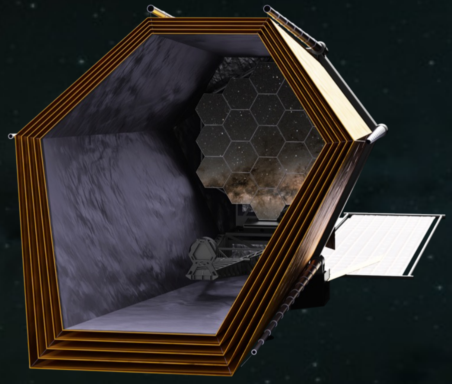
Preliminary architecture option

This is not what HWO will eventually look like!

Preliminary specs & candidate instruments

Telescope

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



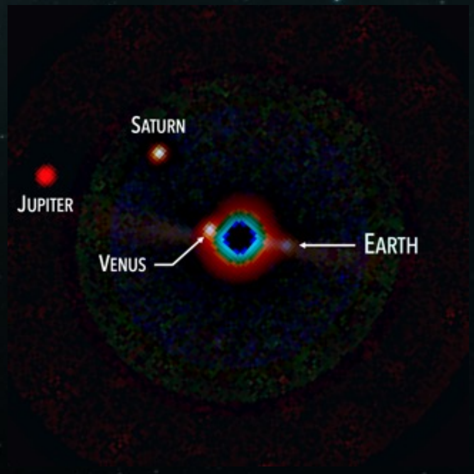
Fourth Instrument

To be defined

Coronagraph

High-contrast imaging and imaging spectroscopy

Bandpass	~200–1800 nm
Contrast	$\lesssim 1 \times 10^{-10}$
R ($\lambda/\Delta\lambda$)	Vis: ~140 NIR: ~70, 200



High-Resolution Imager

UV/Vis and NIR imaging

Bandpass	~200–2500 nm
Field-of-View	~3′× 2′

60+ 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	~2′× 2′
Apertures	~840 × 420
R ($\lambda/\Delta\lambda$)	~500–60,000

NASA's principles for HWO development

Build to schedule

- Mission Level 1 Requirement (e.g., Planetary mission strategy)

Evolve technology

- Build upon current NASA investments and TRL-9 technology
- JWST segmented optical telescope system
- Roman coronagraph

Next generation rockets

- Larger telescope aperture sizes
- Leverage opportunities offered by large fairings to facilitate mass & volume trades

Planned in-space servicing

- Robotic servicing at Sun-Earth L2

Robust margins

- Design with large scientific, technical, and programmatic margins

Mature technologies first

- Reduce risk by fully maturing the technologies prior to development phase

Dr. Mark Clampin, NASA Astrophysics Director, APAC presentation (slide 33) – March 29, 2023

High-level summary of current activities

HWO Project Office at Goddard initiated on Aug 1, 2024

Will be a multi-center effort

First big job … make a complete plan for Pre-Phase A

Explore the science, engineering, & technology trade space

Develop codes & models

Get everything ready to make good decisions rapidly in Phase A

Current HWO Working Groups

Likely to evolve in future

Science

Galaxy Growth
Ravindranath & Postman

Living Worlds
Arney & Parenteau

Evolution of the Elements
Lee & Scowen

Solar Systems in Context
Robinson & Shkolnik

Ground-Based Astronomy in the 2030s/2040s
Lopez-Morales & Miyazaki

Space-Based Astronomy in the 2030s/2040s
Kataria & Petre

Joint & Community

Inclusion & Mentorship
Beaton & Scannapieco

Science-Engineering Interface
Morrissey & Sitarski

Artificial Intelligence & Machine Learning
Ansdell & Dean

Science Data Simulation
Greene & Tumlinson

Synergies for Future Missions
Gaskin & Oschmann

Science Case Simulation
Batalha & Osten

Technical

Post-Processing & ConOps
Mawet & McElwain

Integrated Modeling Standards & New Methods
Levine & Liu

Servicing
Van Campen & Grunsfeld

Working groups include international participants

Science & Joint Working Group Activities

HWO Science Goals	Goals to Objectives	Objectives to Measurements	Measurements to Observations
High-level questions	Define investigations	Determine physical parameters to measure	Define needed observations
"How did the seeds of Solar System planets first come together?"	*"Discover trans-Neptunian objects down to sizes that distinguish between different planetesimal formation scenarios"*	*"Detection of 30 TNOs with diameters ~ 4 km out to 40 AU to constrain the small end of the size distribution at X precision"*	"Detection of R $\leq$ 31.5 mag objects at SNR $\gtrsim$ 5 in a 0.017 deg^2 region imaged in R band"

This work feeds the first four columns of a future Science Traceability Matrix (STM).

In parallel, we want to …

Science & Joint Working Group Activities

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Quantify science returns as functions of observatory capabilities.

Determine correlations & derivatives.

Start building an integrated science model that will connect to the integrated engineering model.

Dynamic Integrated Science Return Analysis (DISRA)

Technical Activities – Exploratory Analytic Cases (EACs)

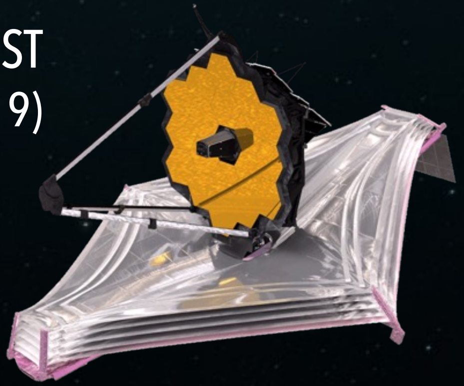
These are 1st round mission architectures that will be used to explore the HWO trade space. Purposes …

- Practice end-to-end modeling, from science to engineering. Develop initial codes to "pipeclean" the process
- Use EACs to identify key technology gaps and guide maturation of potential technology solutions
- Provide feedback to rocket vendors as soon as possible to help influence their direction

We don't expect any of the cases studied now will become a baseline design going forward.
These are only coarse models intended to explore and practice.

Early JWST (at end of Pre-Phase A)

Final JWST (TRL 9)



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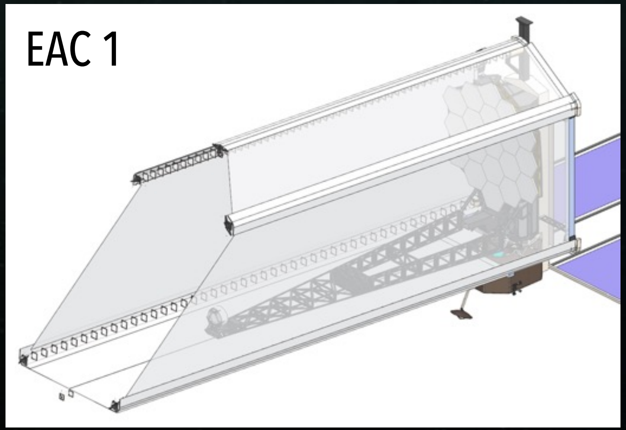
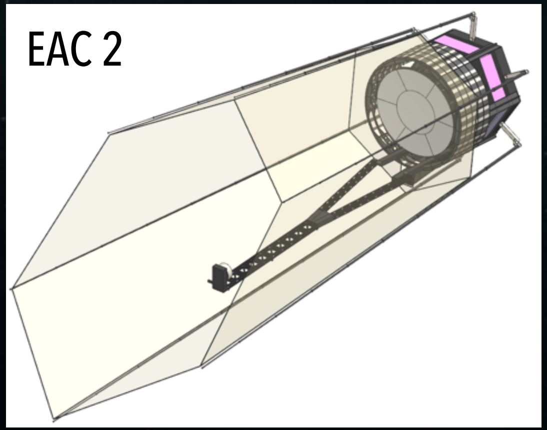
Exploration of three Round 1 EACs will take ~ 1 year. Findings will fold into Round 2 EACs.



6-m inner diameter / 7.2-m outer diameter off-axis



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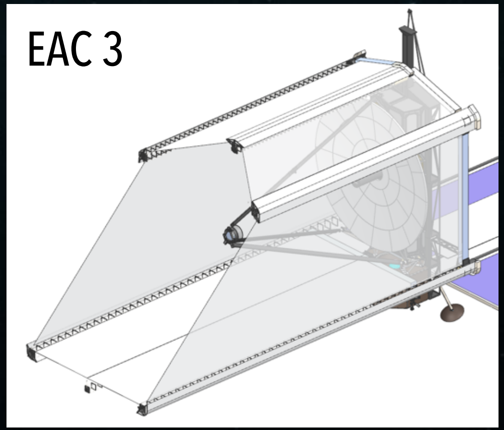

8-m diameter on-axis

Get involved in HWO

Info and updates on NASA HWO Website

Subscribe to HWO-News email list

NASA HWO Website

Join HWO_Community Slack workspace

Slack Join Link

Volunteer for Working Groups & sub-Working Groups

Info on HWO Working Groups presented in Splinter Meeting at Jan 2024 AAS (recording available on website)

Email me for contact info
Aki.Roberge@nasa.gov

OR

Put a message in the Slack