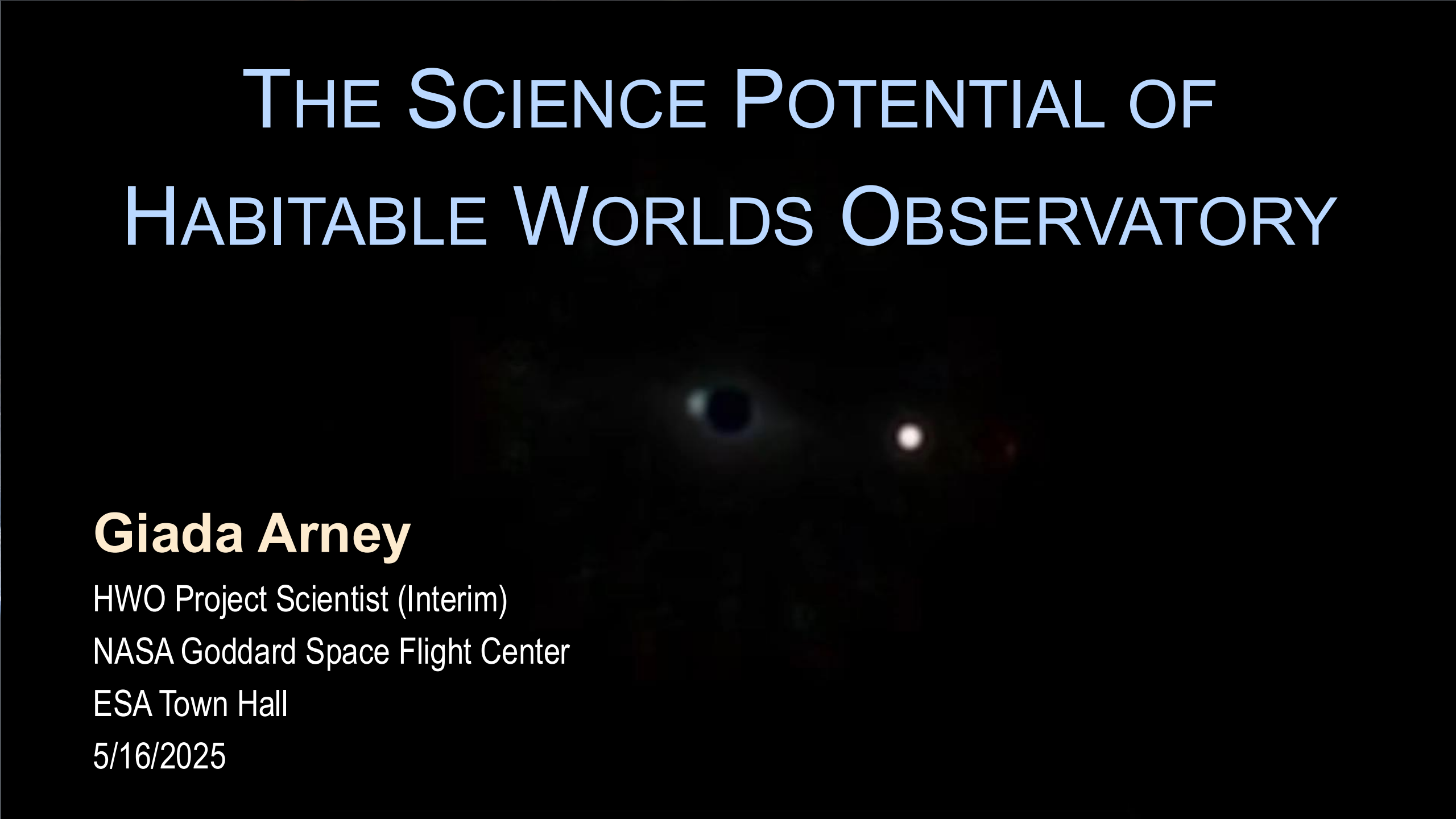
The Science Potential of Habitable Worlds Observatory



Giada Arney

HWO Project Scientist (Interim)

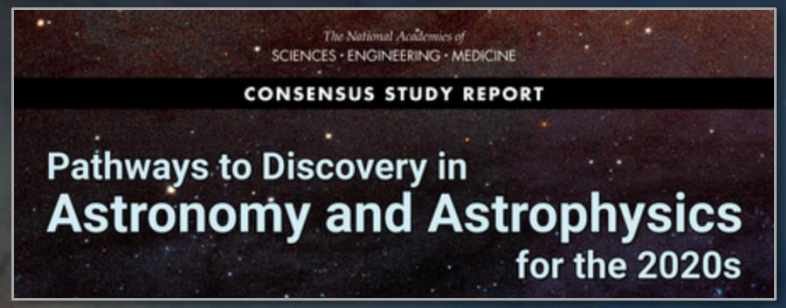
NASA Goddard Space Flight Center

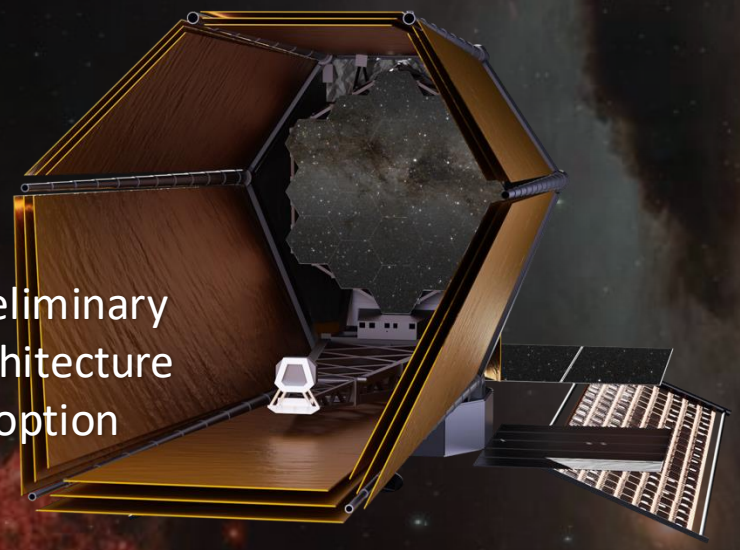
ESA Town Hall

5/16/2025

What is Habitable Worlds Observatory (HWO)?

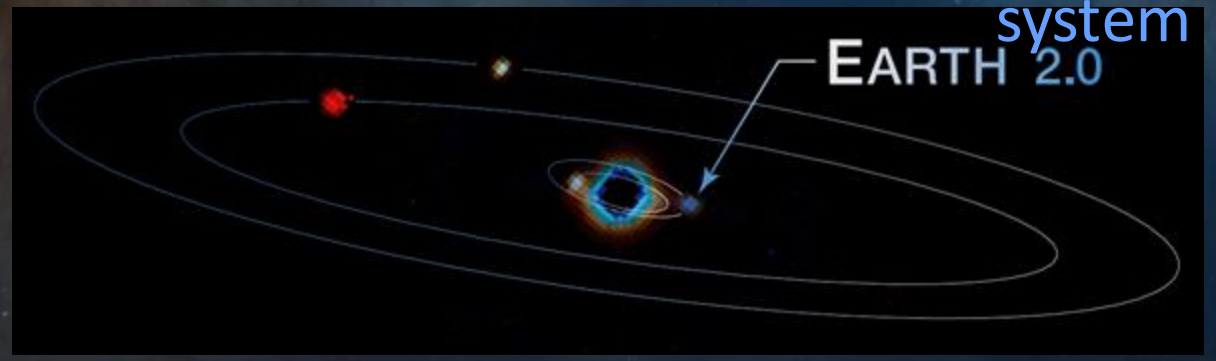
NASA's next flagship mission concept recommended by Astro2020 Decadal Survey





Preliminary architecture option

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

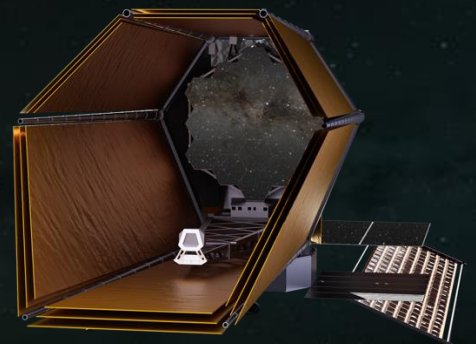


Large-aperture UV / Optical / NIR space telescope performing transformative astrophysics

PRELIMINARY SPECS & CANDIDATE INSTRUMENTS

Telescope

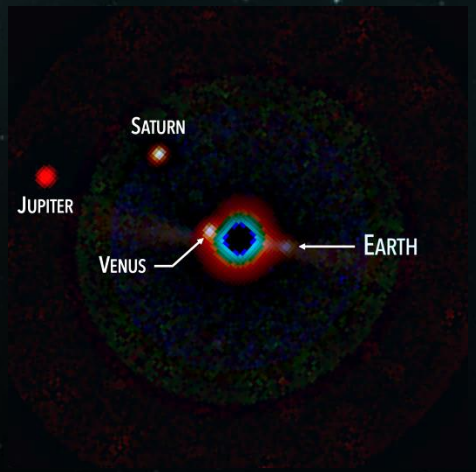
Diameter	~6-8 m (inner)
Bandpass	~100–2500 nm



Coronagraph

High-contrast imaging and imaging spectroscopy

Bandpass	~450 - 1700 nm
Contrast	$\lesssim 1 \times 10^{-10}$
R ($\lambda/\Delta\lambda$)	Vis: ~140 NIR: ~40



High-Resolution Imager

UV/Vis and NIR imaging

Bandpass	~200–2200 (TBD) nm
Field-of-View	~$3' \times 2'$

60+ science filters & grism

High-precision astrometry?

UV Multi-Object Spectrograph

UV/Vis multi-object spectroscopy and FUV imaging

Bandpass	~90 – 700 nm
Field-of-View	~$2' \times 2'$
Apertures	~840×420
R	

Other Possible Instrument(s)

May include NUV coronagraph, NUV starshade, UV/VIS IFS, Spectropolarimeter

International contributions will be considered.

HWO Leadership

NASA HQ

Program Executive	Program Scientist	Deputy Program Scientist
		
Julie Crooke	Megan Ansdell	Joshua Pepper

Technology Maturation Project Office (TMPO)

Principal Architect	Project Manager (interim)	Mission Systems Engineer (acting)	Project Scientist (interim)	Pre-Formulation Scientist (interim)	Pre-Formulation Scientist (ex-officio)	Pre-Formulation Architect (ex-officio)
						
Lee Feinberg GSFC	J. Scott Smith GSFC	Alice Liu GSFC	Giada Arney GSFC	Aki Roberge GSFC	Bertrand Mennesson JPL	John Ziemer JPL

HWO Community

SCIENCE WORKING GROUPS

- Galaxy Growth
  Ravindranath & Postman
- Solar Systems in Context
  Robinson & Shkolnik
- Living Worlds
  Arney & Parenteau
- Evolution of the Elements
  Lee & Scowen

Four science working groups have delivered 65+ science cases

Working groups will conclude on August 1

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COMMUNITY SCIENCE & INSTRUMENT TEAM

- ~20 Members
- 2 co-chairs identified

CSIT to help project explore science & instrument trade space, develop draft requirements, serve as community ambassadors

CSIT will begin work this summer & will include international ex-officio members

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International Agency Involvement In HWO Right Now

JAXA

Dr. Takahiro Sumi
Osaka University

Dr. Satoshi Miyazaki
NAOJ

CSA

Dr. Christain Marois
NRC-Herzberg

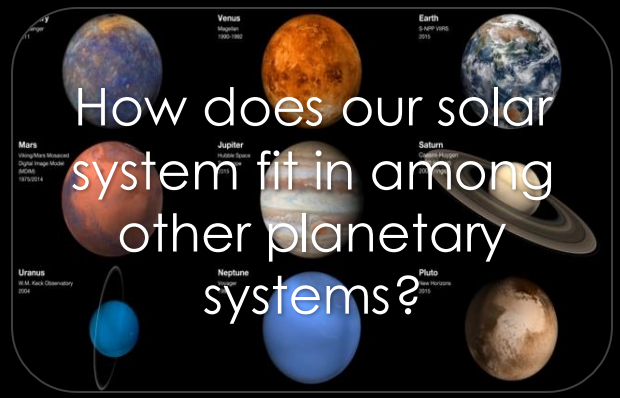
ESA

Dr. Ana Gomez de Castro
Madrid

Dr. Michiel Min
SRON

Dr. David Mouillet
Grenoble

What is the nature of dark matter?



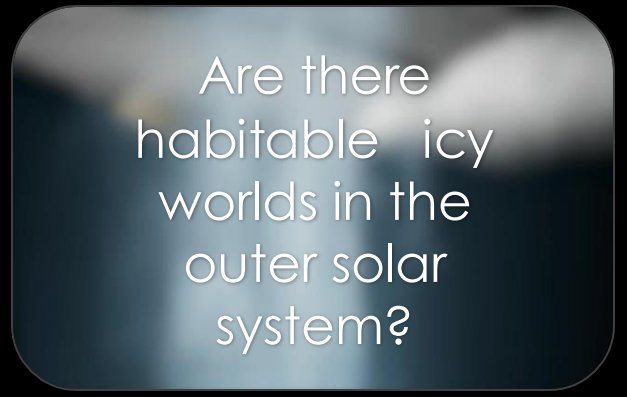
How does our solar system fit in among other planetary systems?

How does galactic star formation propagate and why do massive galaxies stop forming stars?

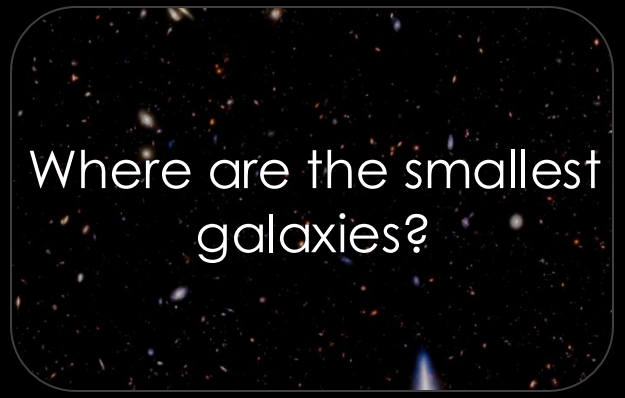
How are heavy elements recycled by galaxies?

How many black holes are in the Milky Way?

HABITABLE WORLDS OBSERVATORY



Are there habitable icy worlds in the outer solar system?



Where are the smallest galaxies?

How do the most chemically primitive stars live and die?

Is there life on exoplanets?

How do the most massive black holes form?

Living Worlds Working Group

Explore finding & characterizing potentially habitable exoplanets and searching them for the possibility of life with HWO

Co-Chairs

Giada Arney (GSFC)

Niki Parenteau (Ames)

Biosignature Possibilities

Eddie Schwieterman (UC Riverside)

Sara Walker (ASU)

Biosignature Interpretation

Stephanie Olson (Purdue)

Josh Krissansen-Totton (U of Washington

Steering Committee

Kevin Fogarty

Ravi Kopparapu

Jake Lustig-Yaeger

Mark Moussa

Garima Singh

Sukrit Ranjan

Clara Sousa-Silva

Target Stars & Systems

Eric Mamajek (JPL)

Natalie Hinkel (Lousiana State)

Selected Living Worlds Priorities

Are Earth-like global biospheres common or rare in the galaxy?

Place the first constraints on the distribution of Earth-like biospheres in the galaxy, with considerations of the biosignatures of Earth through time and strategies to avoid biosignature false positives.

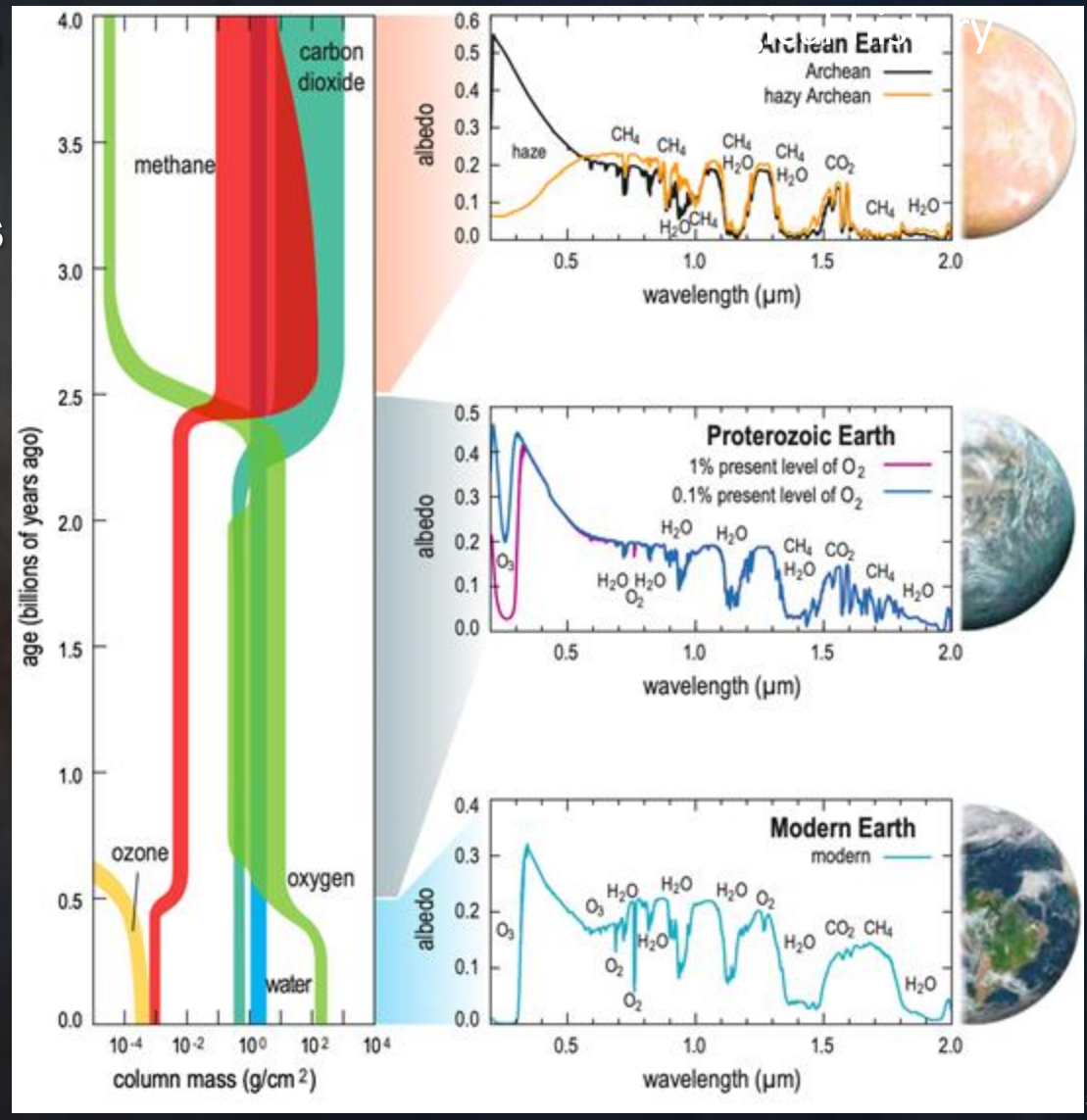
Key needs

Coronagraph able to characterize Earth-sized planets in HZ around sun-like stars. Ability to observe & characterize ≳ 25 Exo-Earth candidates from 0.25 - 1.7 μm

Sample size & need for small NIR IWA pushes on aperture

Astrometry to measure planet masses would be useful

Earth's spectrum, including biosignatures, over our planet's



Solar Systems in Context Working Group

Explore UVOIR imaging and spectroscopy of Solar System objects at all scales, along with exoplanet observations to understand the full range of planet possibilities and histories

Co-Chairs

Evgenya Shkolnik (Arizona State)

Tyler Robinson (U of Arizona)

Characterizing Exoplanets
Renyu Hu (JPL)
Michiel Min (SRON)

Solar System Observations
Lynnae Quick (GSFC)
Richard Cartwright (JHU-APL)

Birth & Evolution
Meredith MacGregor (JHU)
Yasuhiro Hasegawa (JPL)

Demographics & Architectures
Jessie Christiansen (NExScI)
Malena Rice (Yale)

Selected Solar Systems in Context Priorities

Ocean world habitability in the solar system Do icy solar system moons harbor habitable interiors?

Understanding the prevalence, origins, and evolution of surface habitability on rocky exoplanets Can we confirm oceans on exoplanets? How does habitability fit into the broader picture of exoplanetary systems?

How do planets form and grow within their birth environments? Imaging & spectropolarimetry on protoplanets & disks to study how planets form/evolve in birth environments.

Key Needs

UV/VIS IFS; NIR IFS out to 5 um

Coronagraph w/ 10^{-11} contrast. Small IWA = needed for oceans at crescent phase (glint) 30-60 mas. Outer planet cases need large OWA~ 1". Coverage 0.4 – 1.8 µm

Spectropolarimetry

Simulated Europa plumes observed with 8m HWO

UV hydrogen Lyman-α emission with HWO

Credit: Ballester (LPL) / Juanola-Parramon (GSFC)

Evolution of the Elements Working Group

Trace the rise of the periodic table via studies of the formation, distribution, evolution, and deaths of stars

Co-Chairs

Janice Lee (STScI)

Paul Scowen (NASA GSFC)

Star Formation

Roberta Paladini (IPAC-Caltech)

Samir Salim (Indiana U)

Cosmic Explosions

Eric Burns (Louisiana State U)

Jennifer Andrews (Gamini-NOIRLab)

Stellar Populations

Peter Senchyna (Carnegie Observatories)

Martin Barstow (U Leicester)

Selected Evolution of Elements Priorities

Massive Stars in Metal-Poor Environments First detailed constraints on massive star evolution under early-Universe conditions (shown at right)

How do evolutionary processes shape cosmic ecosystems? How do galaxies stir the pot? Want accurate, multi-phase chemical abundances of C, N, Si to study chemical evolution across cosmic time.

Distance Ladder 3.0 Resolve discrepancies in the measurement of the Hubble Constant across differing scales using primary indicators.

Some Key Needs

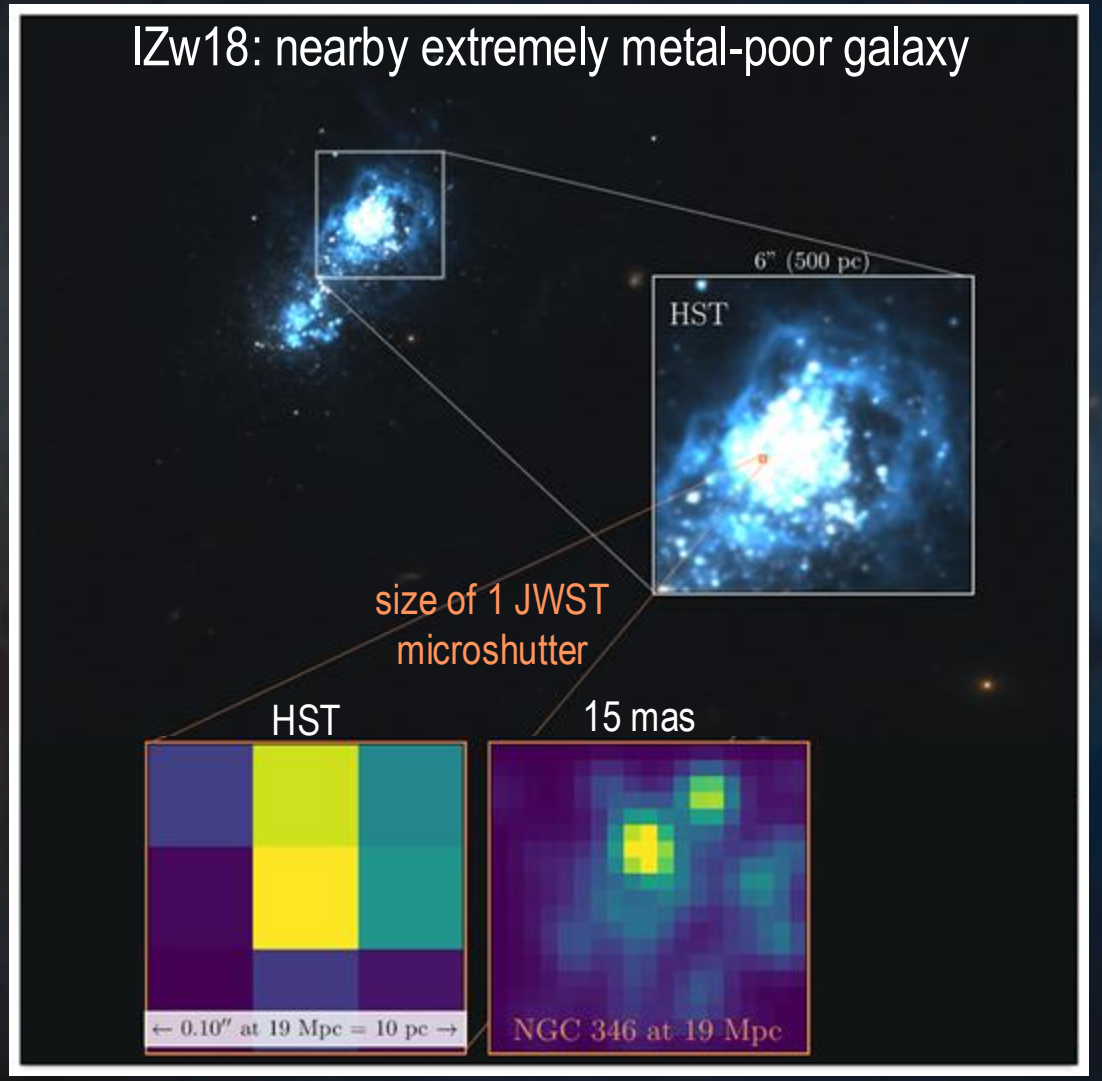
UV MOS, UV IFS, high res imager (UV-NIR); spectropolarimetry needed by some cases; access to 100 nm or even 90 nm

Aperture needs driven by resolution needs (~15 mas).

High throughput

V < 33

Large FOV needed by some science cases (10”x10”)



P. Senchyna (Carnegie) et al.

Galaxy Growth Working Group

Study how galaxies, constituents, and their environments evolve over the history of the HWO-observable universe

Co-Chairs

Swara Ravindranath (NASA GSFC)

Marc Postman (STScI)

AGN Over Cosmic Time

Vivian U (UC Irvine)

Chris Packham (UT San Antonio)

Ionizing Photons & their History

Stephan McCandliss (JHU)

Alison Strom (Northwestern)

IGM & CGM

Sanchayeeta Borthakur (ASU)

Joe Burchett (New Mexico State)

The Dark Sector

Jason Rhodes (JPL)

Richard Massey (Durham U)

Selected Galaxy Growth Priorities

Constrain the nature of dark matter Measure abundance & small-scale power spectrum of low mass ($\leq 10^7$ solar masses) subhalo masses to constrain existence of warm dark matter & mass of dark matter particle. (At right)

Understanding the cosmic ecosystem Map multiphase flow of gas, which controls star formation & evolution, in & out of galaxies

Ionizing radiation across time First measurements of shape of ionizing radiation from 50-90 nm (in **rest** frame) for large sample of high redshift objects

Some Key Needs

UV MOS, UV IFS, high res imager (UV-NIR); spectropolarimetry by some cases; access to 100 nm or even 90 nm

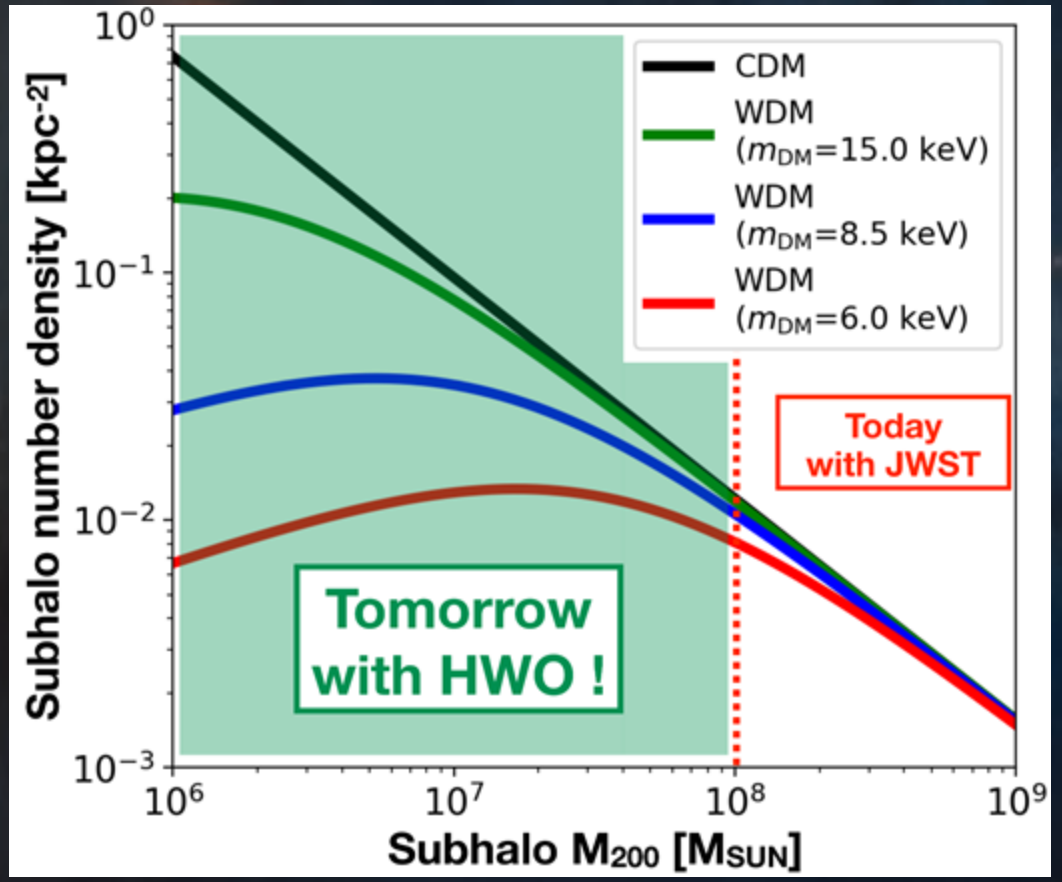
Aperture $\geq$ 8 m needed for adequate sample sizes and resolution

FUV observations down to 32nd magnitude

Some cases need 10”x10” FOV

Astrometry for dark matter, galactic center cases

$\leq 10^7$ subhalo masses constrain theories of warm dark matter



Qiuhan He (Durham U)

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Vision for Community Science Instrument Team

Membership to be announced soon.

CSIT will help Project mature technologies and mission concept, execute scientific studies to support definition of a baseline concept, analyze potential instruments, provide input to technology maturation plans, provide input to develop draft science requirements

International exo-officio members desired and expected. NASA HQ will work with ESA on representation soon.

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Science Interest Group (SIG)

The HWO Project Office & CSIT will work with the broad astronomical community through the three astrophysics program analysis groups (Cosmic Origins, Exoplanet Exploration, Physics of the Cosmos)

This SIG will be the coordinating body for this relationship

Activities expected to include: virtual seminars, advocating for & conducting community-driven analyses (likely via Science Analysis Groups), virtual & face-to-face meetings

Scientists are invited to apply to lead the SIG. Solicitation of interest out today and due June 6. A leadership team of 3-6 members is envisioned.

Membership to be open to the full community, including international community.

Continuing community engagement

Over 1000 participants in the HWO Community Slack and growing!

HWO Monthly Seminar Series

- Intended for broad audiences

HWO News email updates

NASA.gov/hwo has updates and information about the mission

Request invitation to join HWO_Community Slack

Subscribe to HWO-News Instructions on NASA HWO website