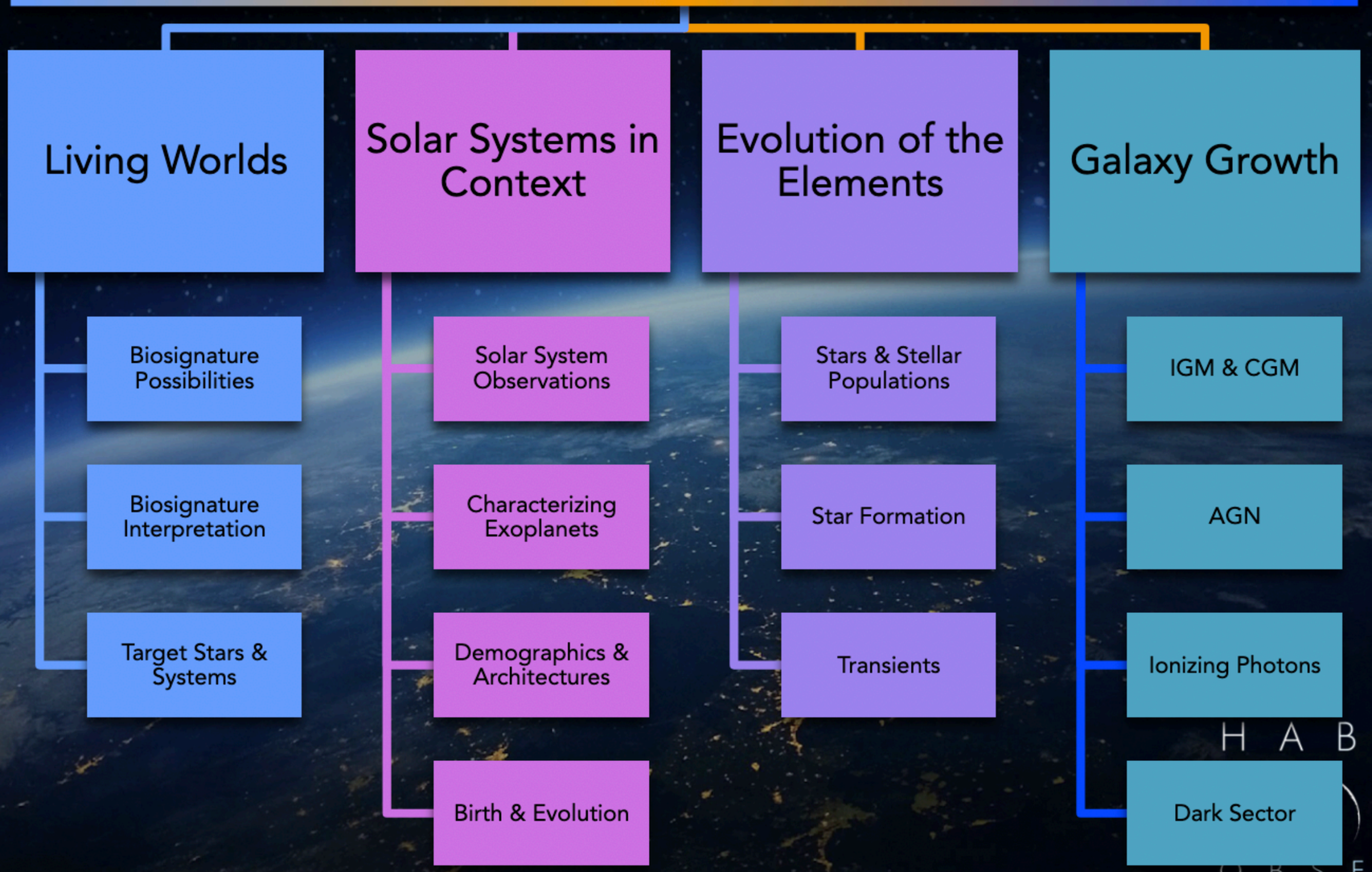
# Exoplanet Demographics & Architectures with the Habitable Worlds Observatory

1/11/2025

Malena Rice, on behalf of the HWO D&A sub-WG

HABITABLE WORLDS OBSERVATORY

# Science Working Groups




HABITABLE WORLDS OBSERVATORY

Adapted from NASA/J. Crooke

# Solar Systems in Context (SSiC)

Evgenya Shkolnik (Arizona State)
Tyler Robinson (U Arizona)

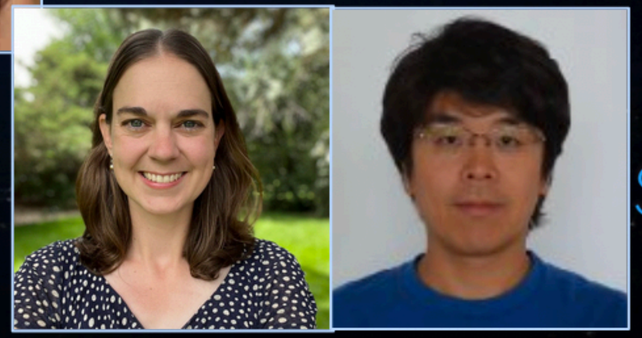
Characterizing Exoplanets
Renyu Hu (JPL)
Michiel Min (SRON)

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

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

Ex Officio
Courtney Dressing (Berkeley)

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



E
S
Y

# Solar Systems in Context (SSiC)

**Goal:**
Develop strategy to answer Solar System and Exoplanet science questions.

- Help set HWO priorities and design.

**Deliverables:**
Science Case Development Documents (objectives, measurements, etc.)

**Structure:**

- 4 interdisciplinary science subgroups
- 800 (!!) unique expressions of interest
- 80+ people actively working on 20 SCDDs

HABITABLE WORLDS OBSERVATORY

**Solar System Observations**

The Case for Venus
Mars Origins
Ocean World Habitability
Solar System Origins

**Characterizing Exoplanets**

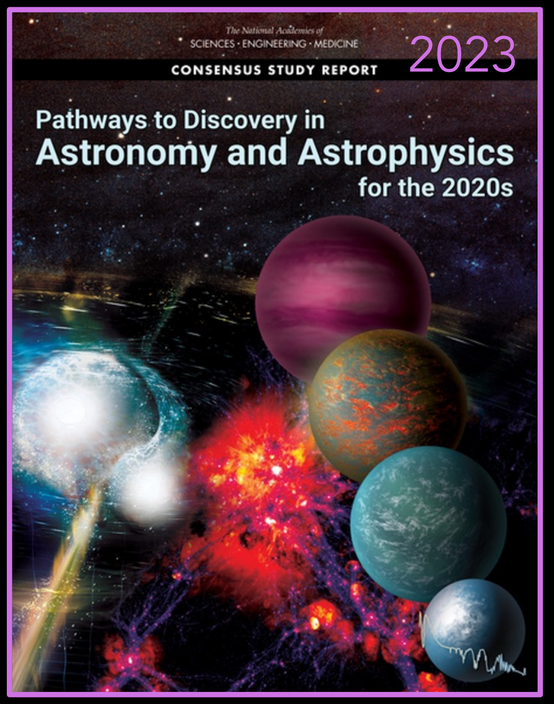
Exoplanet Surface Liquid Water
Rocky Worlds vs Sub-Neptunes
Atmospheric Escape of Small Exoplanets
Reflected Light Spec. of Giant Exoplanets
Transiting Exoplanets
Identify Cold Ocean Worlds
Identify Venus-like Exoplanets

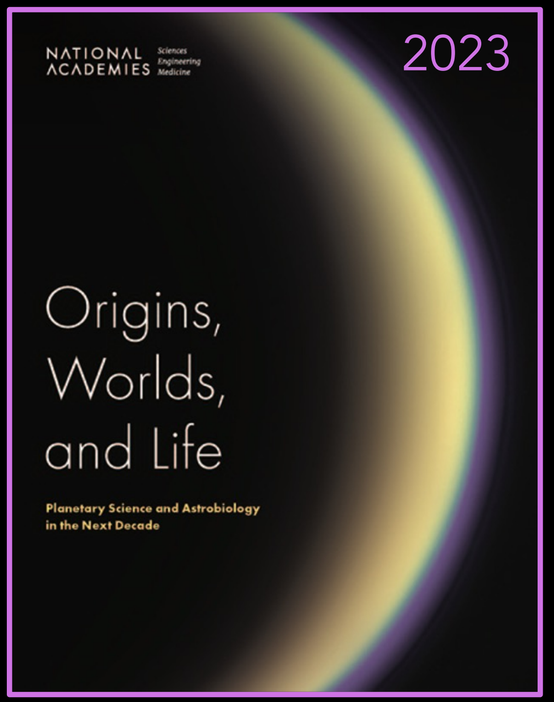
**Birth & Evolution**

Habitability in Planetary System Context
Protoplanets and Protoplanetary Disks
Debris Disks and their Properties
Disk Winds and Dispersal of Protoplanetary Disks

**Demographics & Architectures**

Earth-Like Atmosphere Demographics
Giant Exoplanet Orbital Evolution
Occurrence Rates in Binary Systems
Occurrence Rates of Small Exoplanets



**Solar System Observations**

The Case for Venus
Mars Origins
Ocean World Habitability
Solar System Origins

**Characterizing Exoplanets**

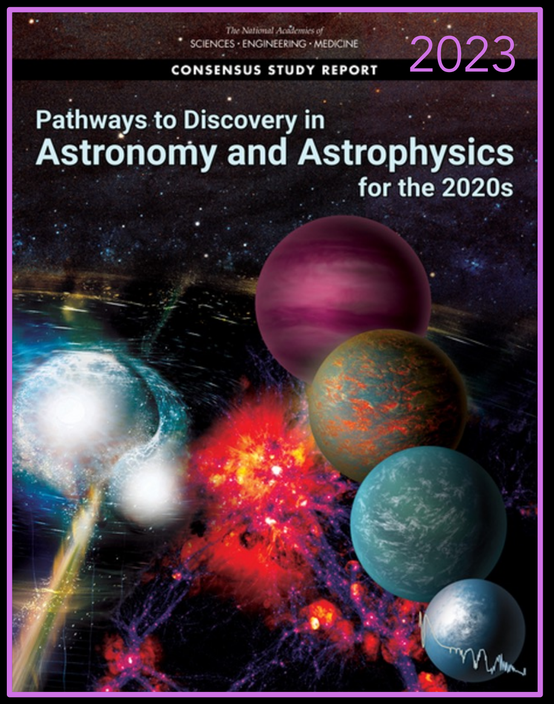
Exoplanet Surface Liquid Water
Rocky Worlds vs Sub-Neptunes
Atmospheric Escape of Small Exoplanets
Reflected Light Spec. of Giant Exoplanets
Transiting Exoplanets
Identify Cold Ocean Worlds
Identify Venus-like Exoplanets

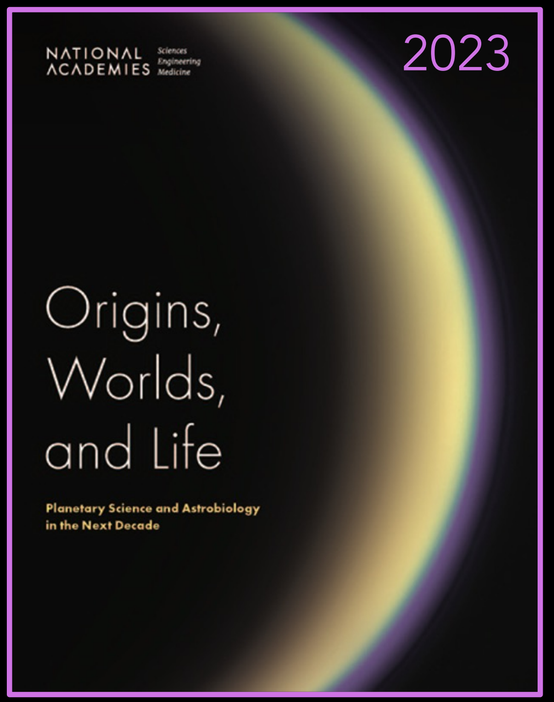
**Birth & Evolution**

Habitability in Planetary System Context
Protoplanets and Protoplanetary Disks
Debris Disks and their Properties
Disk Winds and Dispersal of Protoplanetary Disks

**Demographics & Architectures**

Earth-Like Atmosphere Demographics
Giant Exoplanet Orbital Evolution
Occurrence Rates in Binary Systems
Occurrence Rates of Small Exoplanets



# HWO Exoplanet Demographics & Architectures sub-working group

Goal: synthesize current knowledge of exoplanet occurrence rates and system architectures for the types of stars that HWO will target, and assess the sensitivity and accessibility required to constrain system architectures.

# HWO Exoplanet Demographics & Architectures sub-working group

HWO D&A sub-WG co-leads

Malena Rice (Yale)

Jessie Christiansen (IPAC)

Lead: Giant exoplanet orbital evolution

Sabina Sagynbayeva (Stony Brook)

Stephen Kane (UCR)

Lead: Occurrence rates in binary systems

Elisabeth Newton (Dartmouth)

Lead: Earth-like atmosphere demographics

Sarah Blunt (UCSC)

Eric Nielsen (UNM)

Lead: Occurrence rates of small exoplanets

Tansu Daylan (WashU)

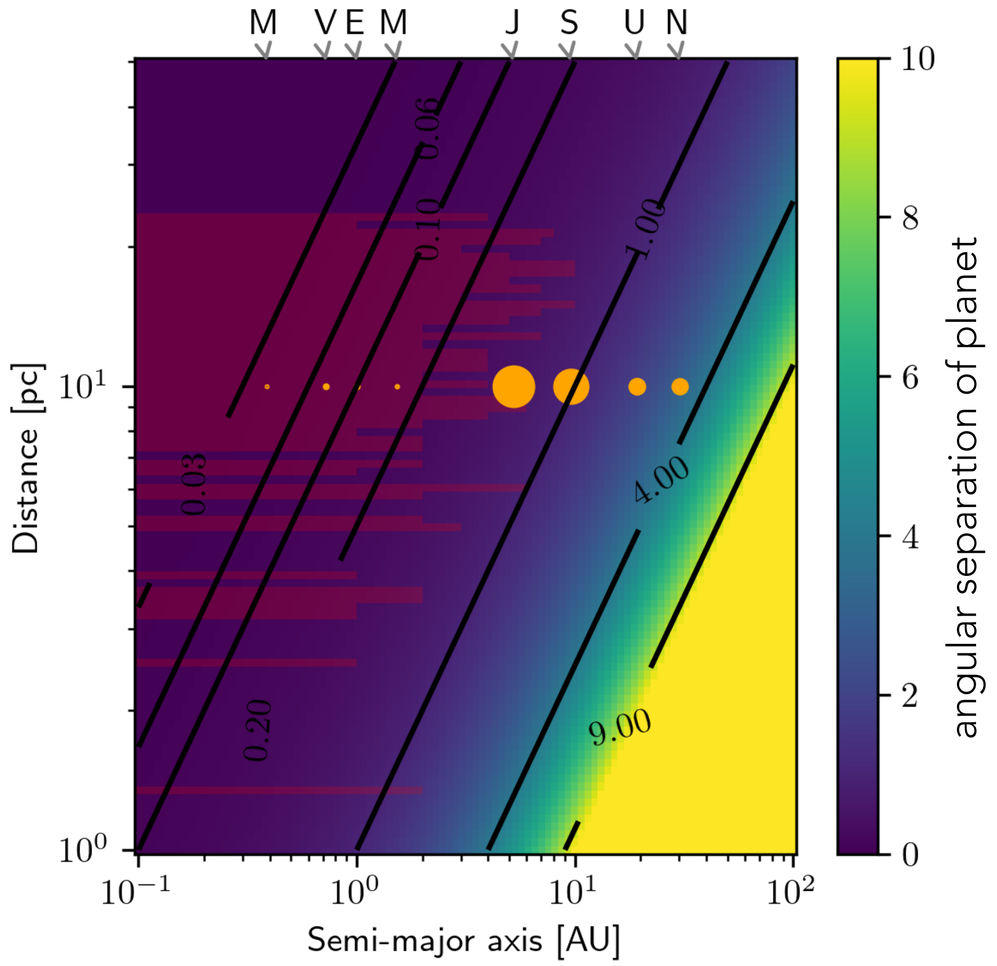
Romy Rodriguez (CfA)

# Occurrence rates of small exoplanets

*What fraction of small, habitable-zone planets exist in architectures similar to that of the solar system?*

Breakthrough requirements:

- 0.6-1.5 microns
- 3-40 λ/D at 0.5 microns
- Contrast of $10^{-11}$



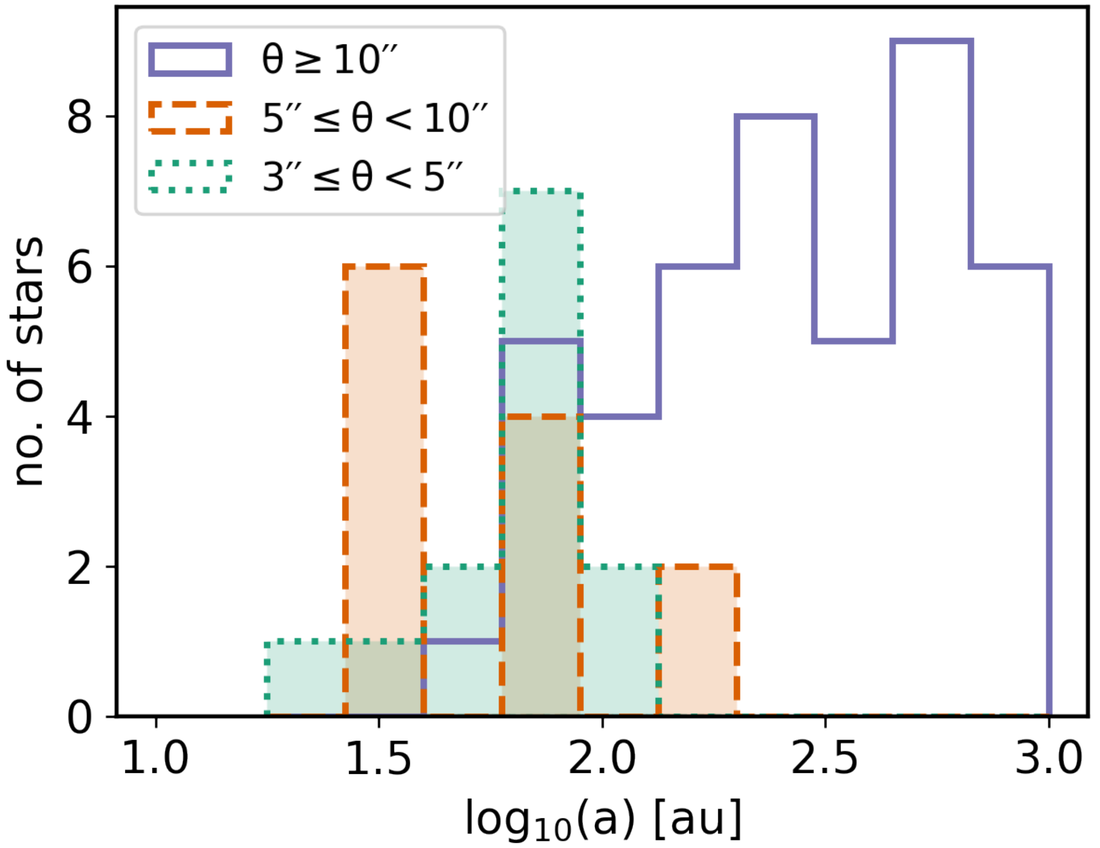

Lead: Tansu Daylan, Romy Rodriguez

# Occurrence rates in binary systems

*Is the formation of potentially habitable planets suppressed, enhanced, or unaffected by the presence of a stellar companion?*

Breakthrough requirements:

- Starlight suppression for angular separations ~3″ and targets 15% more distant than those on the ExEP list, or
- Starlight suppression for angular separations ~5″ and targets 60% more distant
- Census of stellar companions within 30 pc



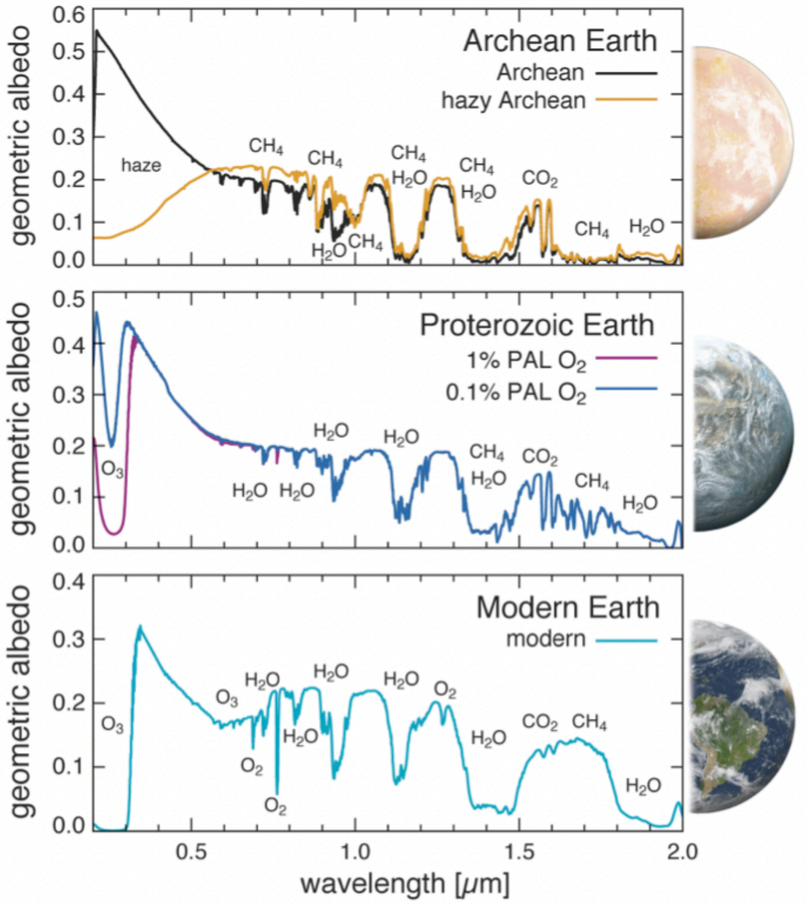

Lead: Elisabeth Newton

# Earth-like atmosphere demographics

*How long after it forms does an Earth-like planet typically get an oxygen-rich atmosphere like modern Earth's?*

Breakthrough requirements:

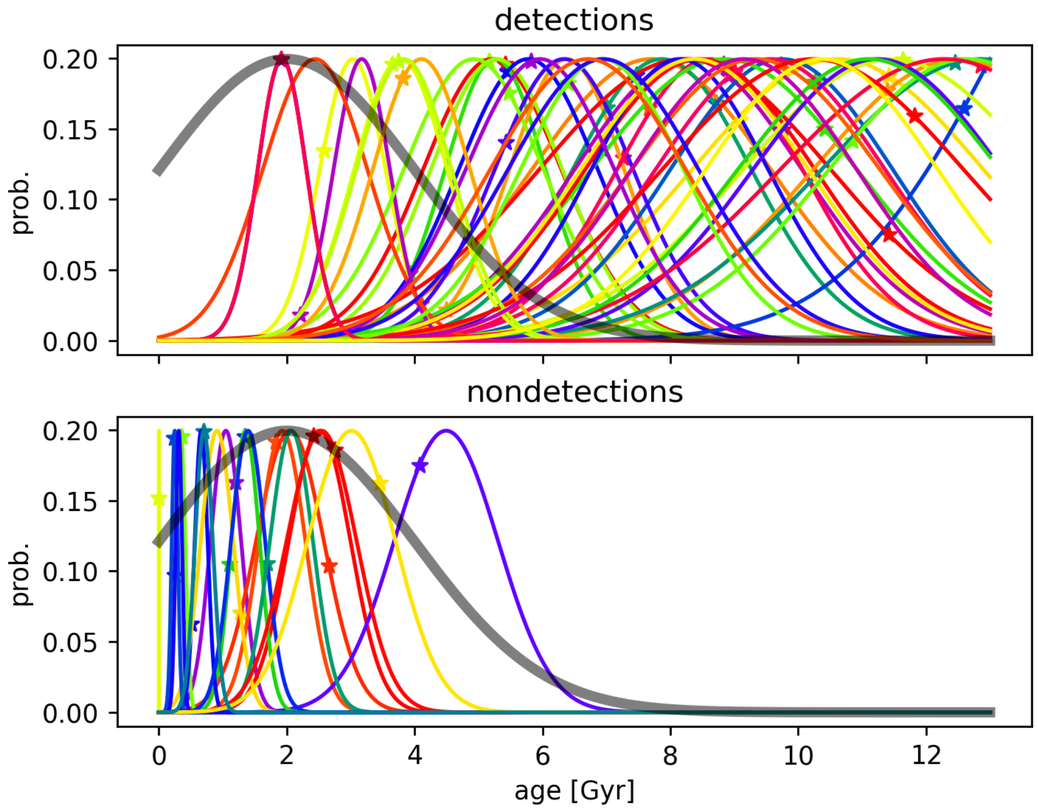
- 0.25-2.5 microns
- UV coverage necessary
- 40 detected Earth analogues with detection (or non-detection) of ozone
- 20% age precision for HWO target stars

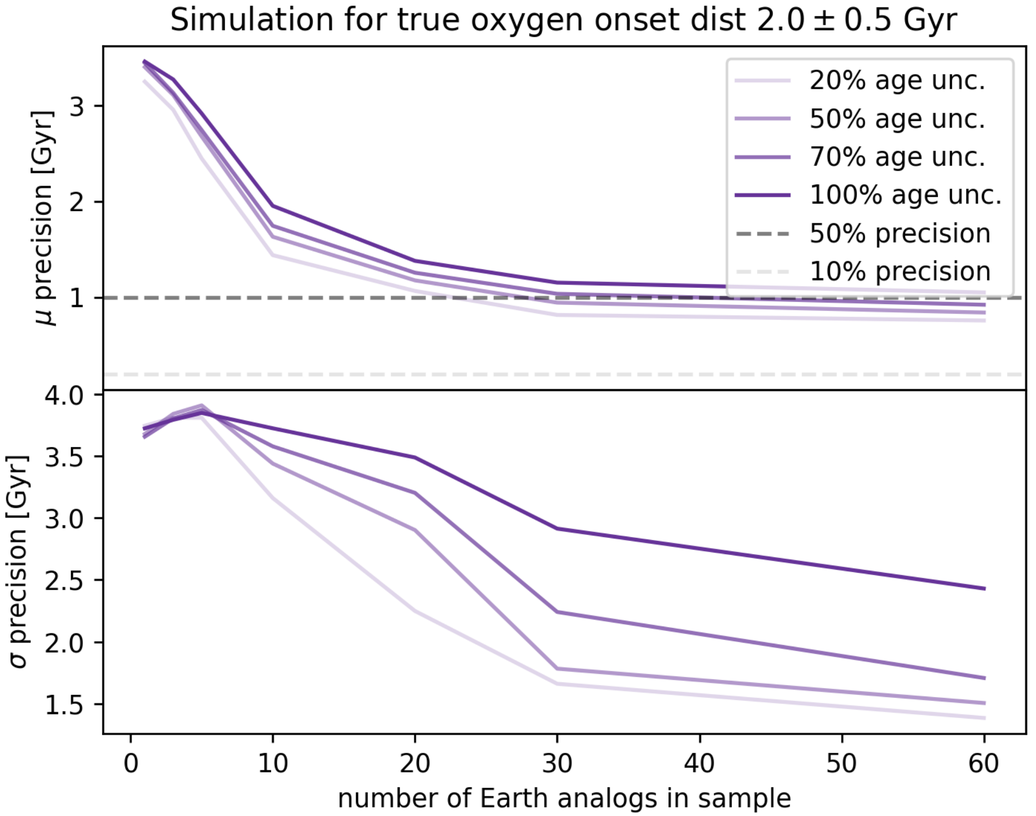



Lead: Sarah Blunt, Eric Nielsen

Blunt et al., in review

# Earth-like atmosphere demographics



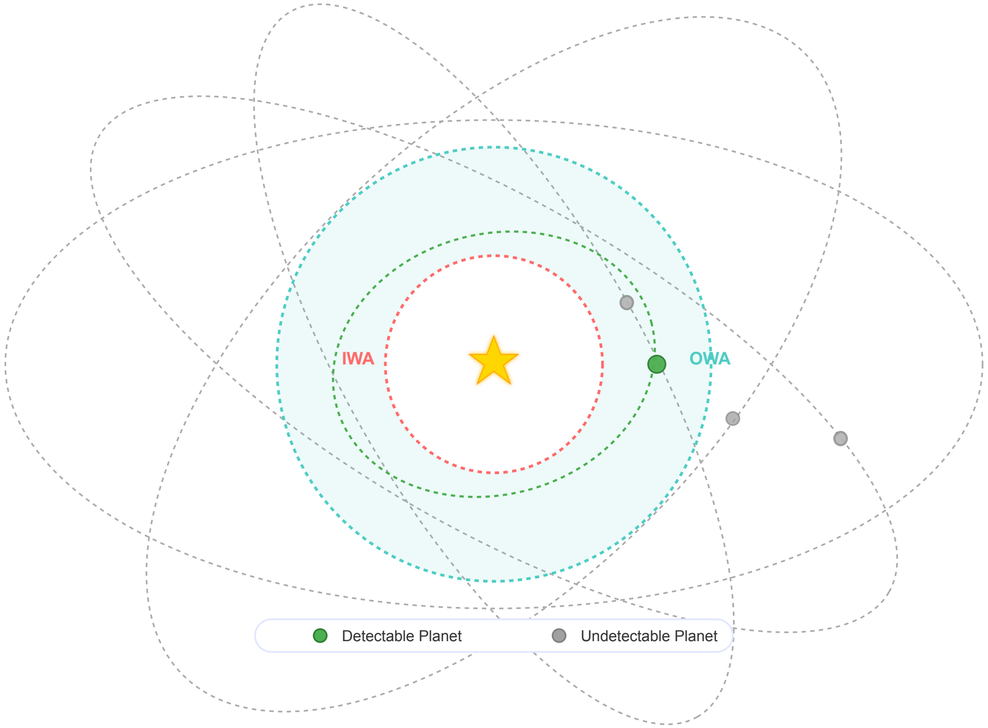




Lead: Sarah Blunt, Eric Nielsen

Blunt et al., in review

# Giant exoplanet orbital evolution

*Which dynamical processes are responsible for the observed orbital architectures of giant planets?*




Breakthrough requirements:

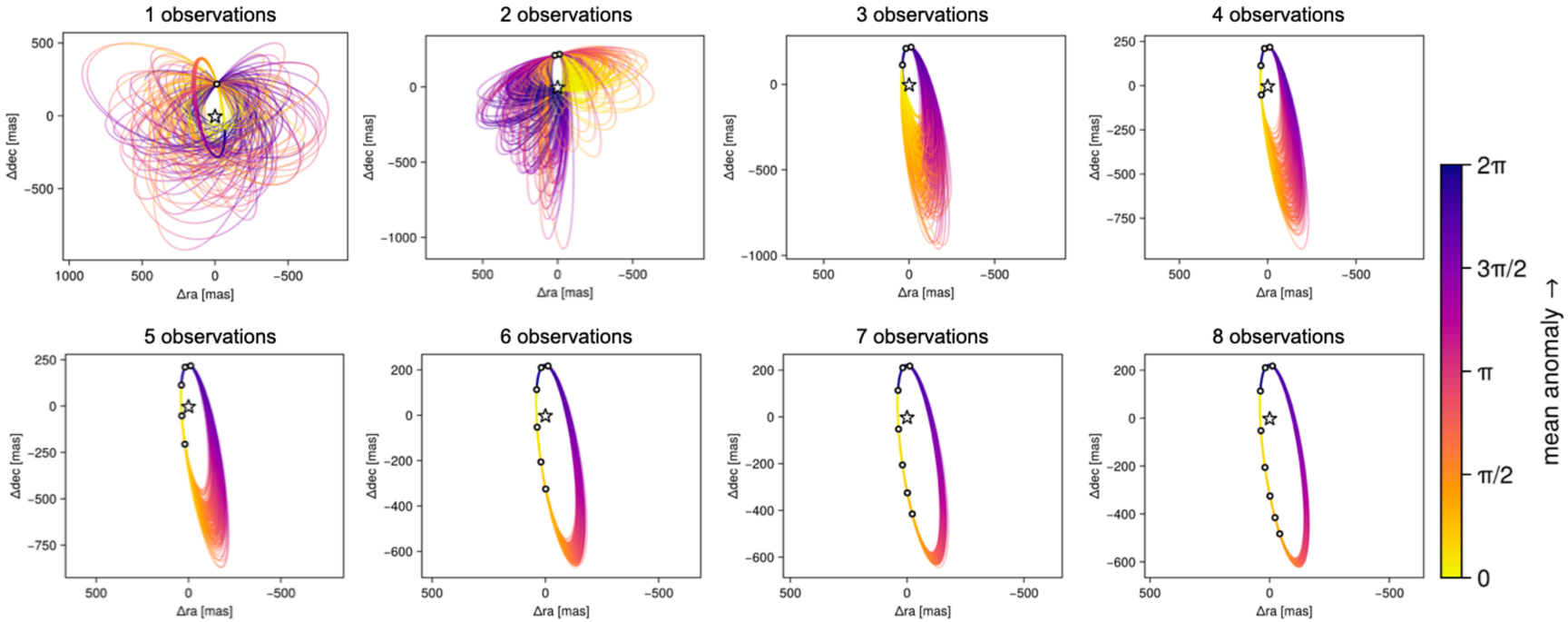
- Sensitivity: < 30.5 mag
- Contrast: 10-9 to 10-10 at 0.1-1” Separation
- IWA of < 0.083”; OWA of > 0.64”

Lead: Sabina Sagynbayeva, Stephen Kane

Sagynbayeva et al., in prep

# Giant exoplanet orbital evolution

Generally ~6-8 epochs needed to constrain orbits and provide reliable HZ characterization




Lead: Sabina Sagynbayeva, Stephen Kane

Sagynbayeva et al., in prep

# General outlook:

- HWO has the potential to provide transformative advances to not only the detection of habitable zone planets, but also our understanding of system architectures and demographics.
- This will likely require considering a broader target list than the nominal 100-star search: ideally at least ~160-200 stars to consider a diversity of systems and build statistical power.
- Precursor observations are critical to lay the foundation for future HWO observations of bright, nearby stars — ages, extended radial velocity monitoring, stellar companion characterization, etc.

HABITABLE WORLDS OBSERVATORY

# Exoplanet Demographics & Architectures with the Habitable Worlds Observatory

1/11/2025

Malena Rice, on behalf of the HWO D&A sub-WG

HABITABLE WORLDS OBSERVATORY