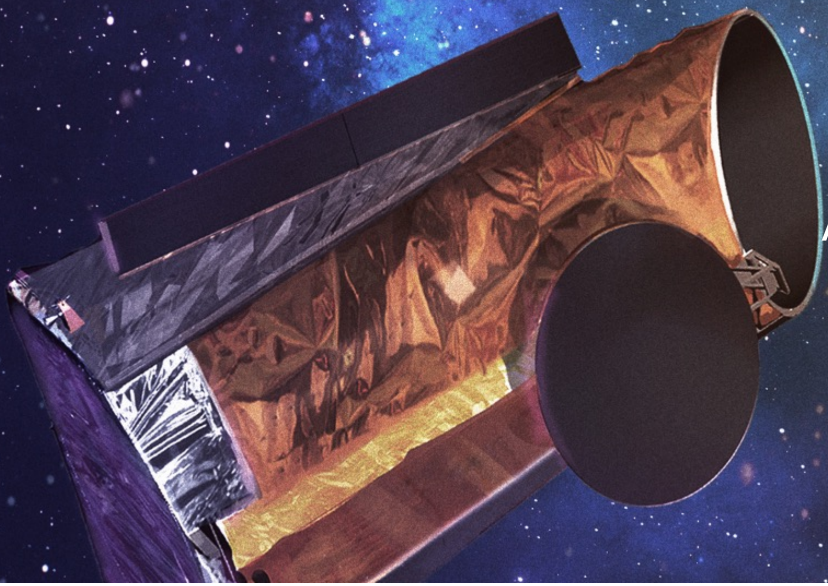
HabEx

The Habitable Exoplanet Observatory

Exploring New Worlds – Understanding Our Universe



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Keith Warfield (JPL – Study Manager)

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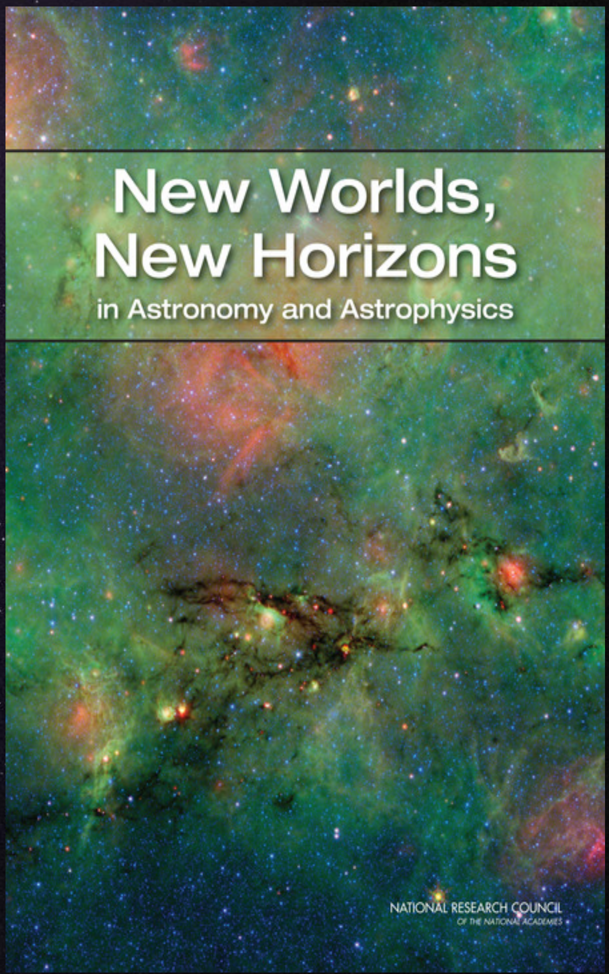
The US Astrophysics Decadal Survey



- For large space-based telescopes –
  - **Astro2000**: James Webb Space Telescope (JWST) ~2021.
  - **Astro2010**: Wide Field Infrared Survey Telescope (WFIRST), ~2025 (Jason Rhodes talk 4pm Sep 25th).
  - **Astro 2020**: Habitable Exoplanet Observatory (HabEx; UV–near-IR) If prioritized, mid-to-late 2030's.
    - The other studies are:
      - Origins Space Telescope (OST; Far-IR)
      - Large UV, Optical, IR Telescope (LUVOIR; UV–near-IR)
      - Lynx (X-ray)

The HabEx Final Report

- 3.5 years
- 178 authors
- 9 architectures
- 552 pages

www.jpl.nasa.gov/habex/pdf/HabEx-Final-Report-Public-Release.pdf

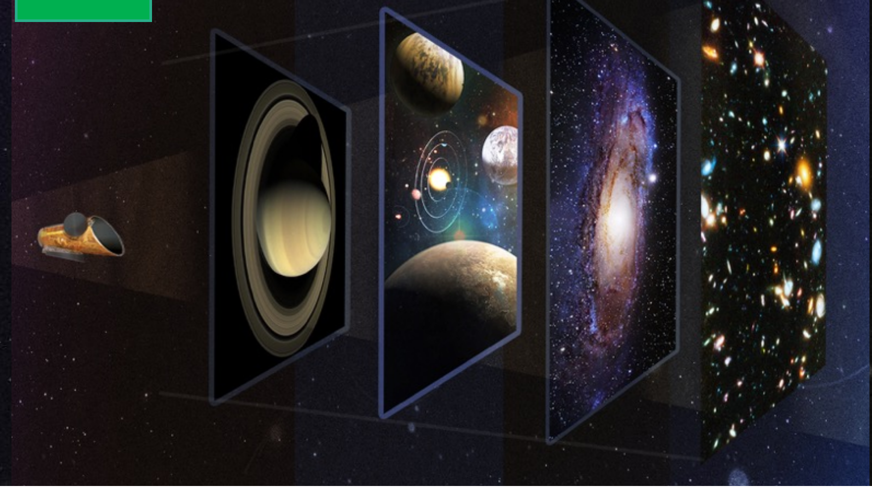
HabEx Study Philosophy

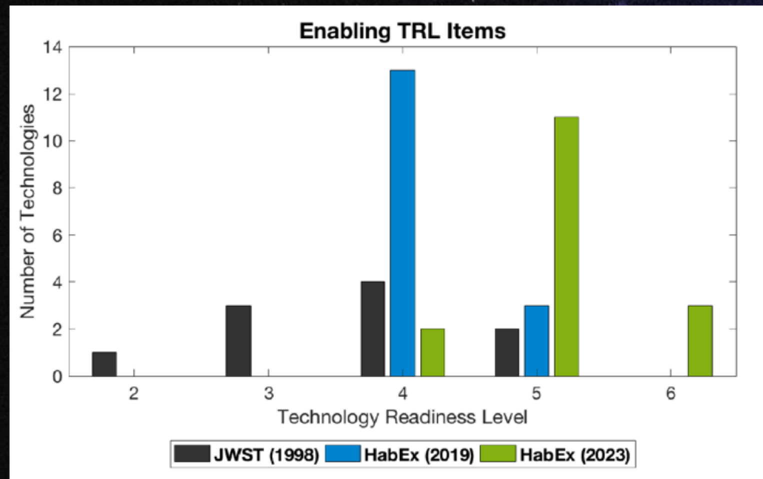
NASA: "Develop an exoplanet direct imaging mission"

HabEx Team:

Maximize

- Science return for both
  - Exoplanet direct imaging
  - Astrophysics & cosmology





HabEx Team:

Minimize

- Cost
- Risk
- Development schedule

Seek out nearby worlds and explore their habitability

Map out nearby planetary systems and understand their diversity.

Enable new explorations of systems in the UV to near-IR

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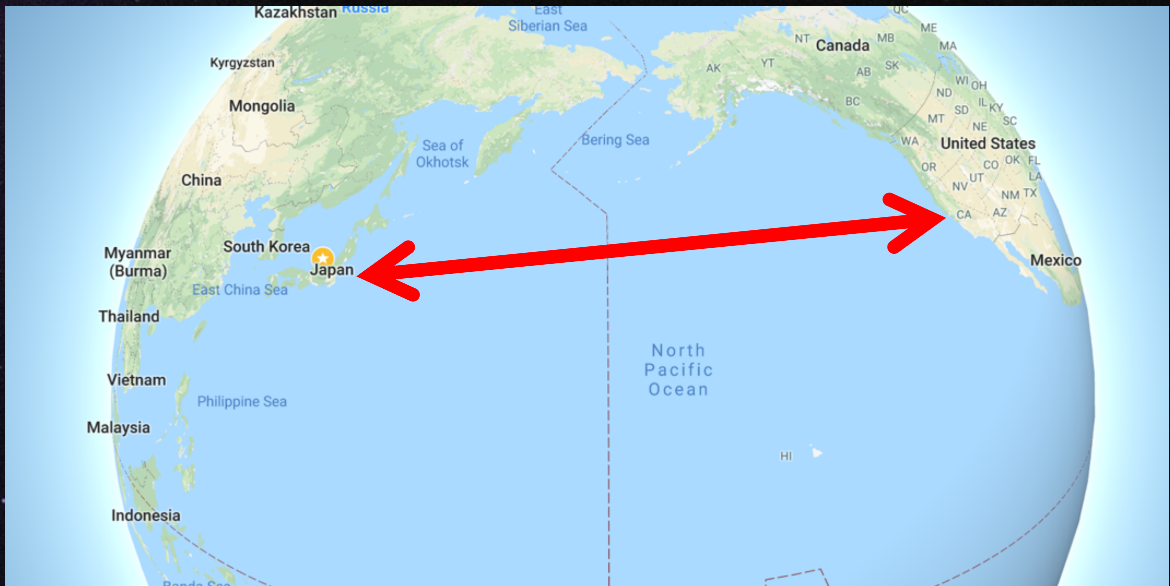
Exoplanet Direct Imaging

Seeing an exoplanet around a star is like trying to see a firefly near a spotlight in Los Angeles… when you are standing in Tokyo!

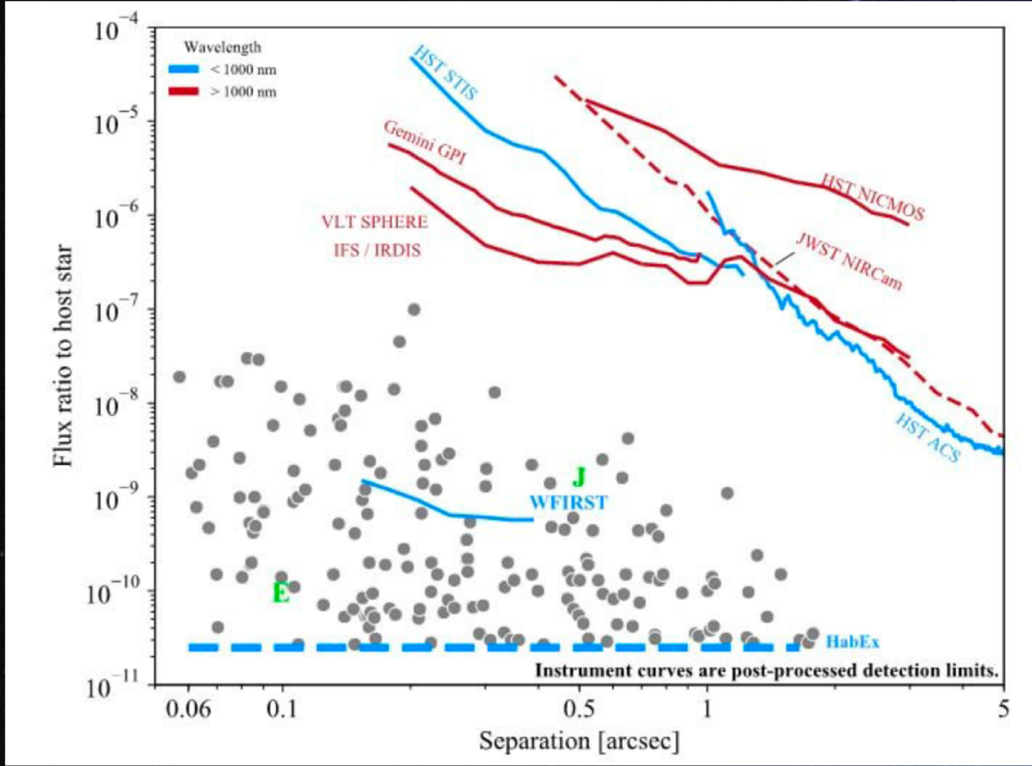


Seeing an Earth-like exoplanet in the habitable zone around a sunlike star is like trying to see a firefly near ONE THOUSAND spotlights in Los Angeles… when you are in standing in Tokyo!

High Contrast Imaging and Spectroscopy

- Contrast Ratio (exoplanet light to star light)

- 10^{-5} 1 part in 10,000
  - What we can get from ground-based coronagraphs now
- 10^{-9} 1 part in 1,000,000,000
  - What WFIRST's coronagraph is being designed to achieve
- 4×10^{-10} 4 parts in 10,000,000,000
  - What we have demonstrated in a lab for WFIRST
- 10^{-10} 1 part in 10,000,000,000
  - What HabEx's coronagraph is being designed to achieve (and what we need to see another Earth)



We have already found a lot of Exoplanets

NExScI

ipac

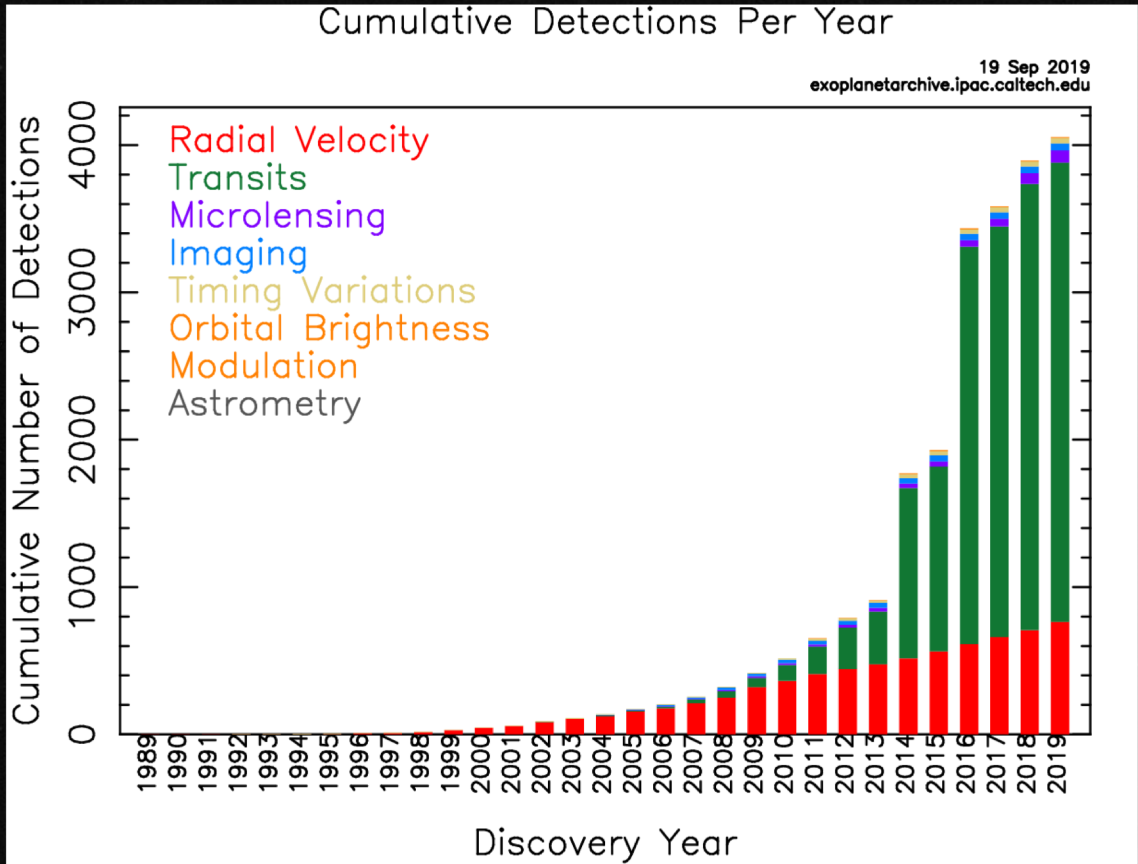
Exoplanets:
Cumulative Detections by Discovery Year

1989-2018

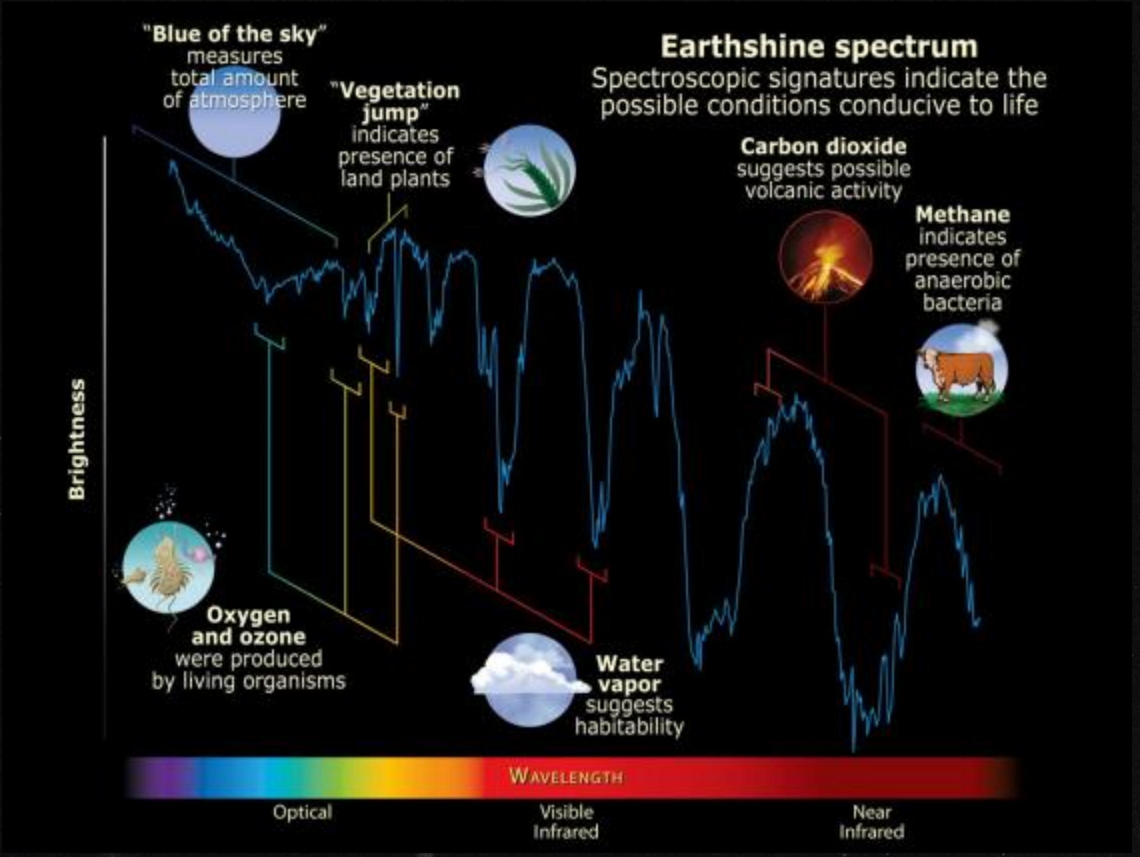
Plots generated Sept. 27, 2018

We have already found a lot of Exoplanets

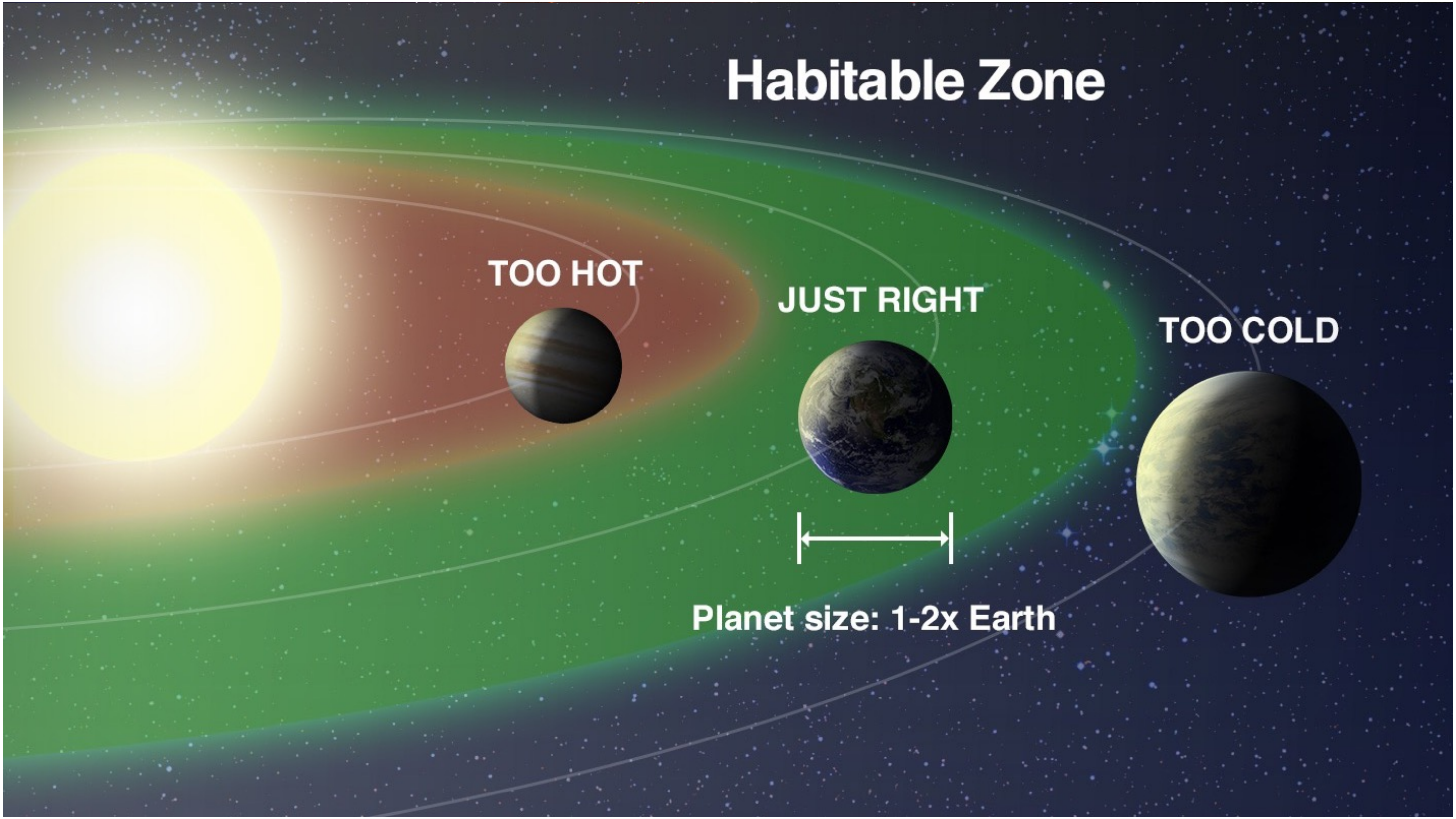
4055 as of 5 days ago!



But we really want to find "Earth 2.0"



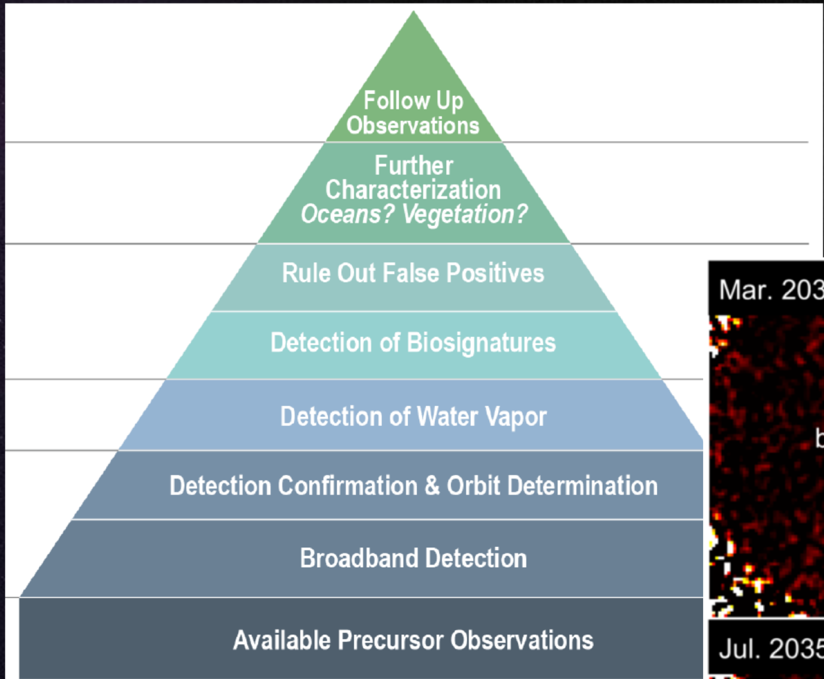
Credit: M. Turnbull

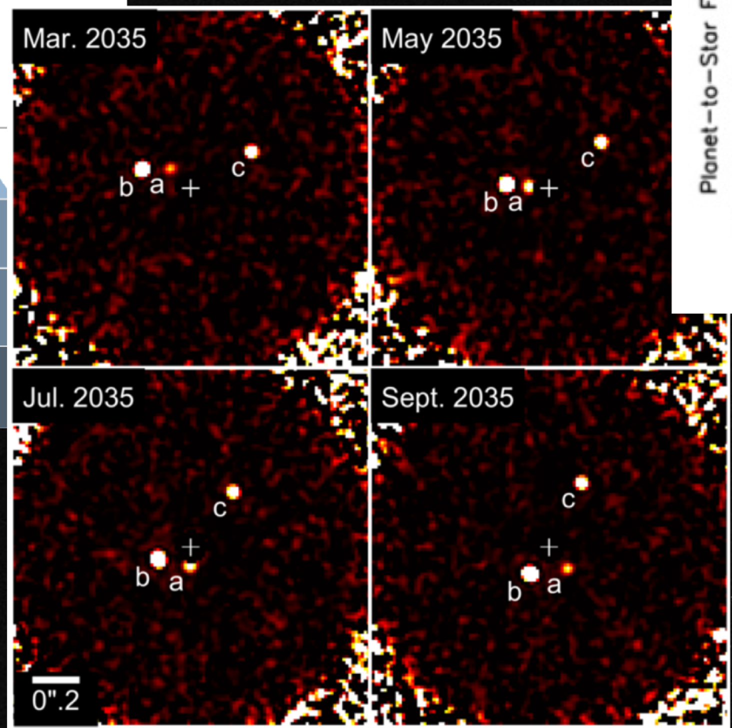

Habitable Zone
TOO HOT
JUST RIGHT
TOO COLD
Planet size: 1-2x Earth

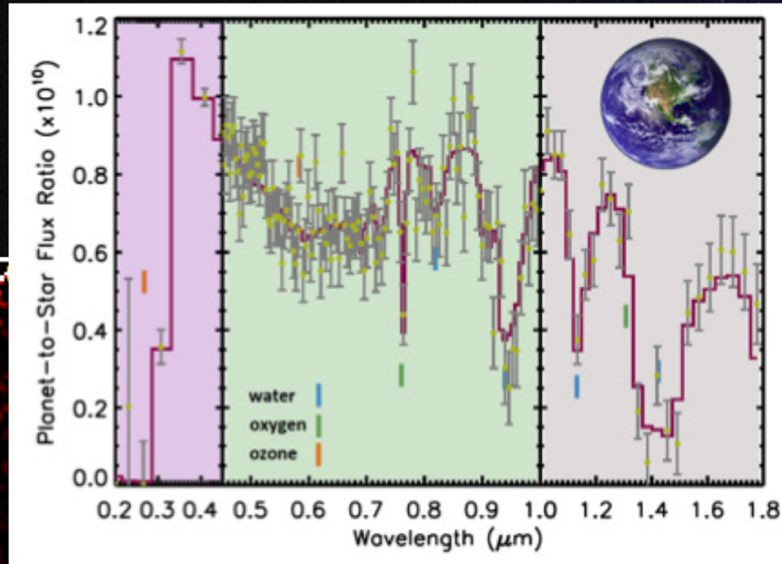
A Familiar Habitable Zone

HabEx

Seeking Potentially Habitable Worlds







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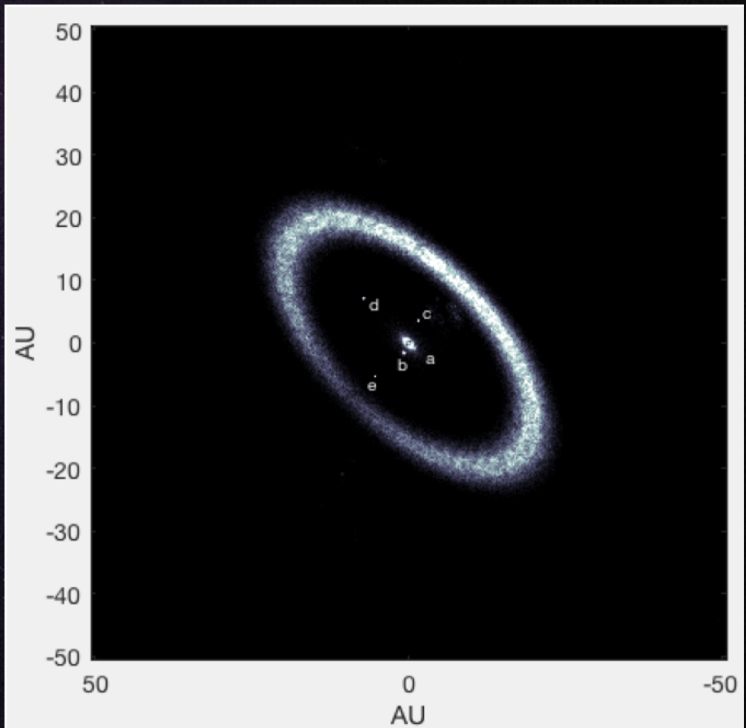
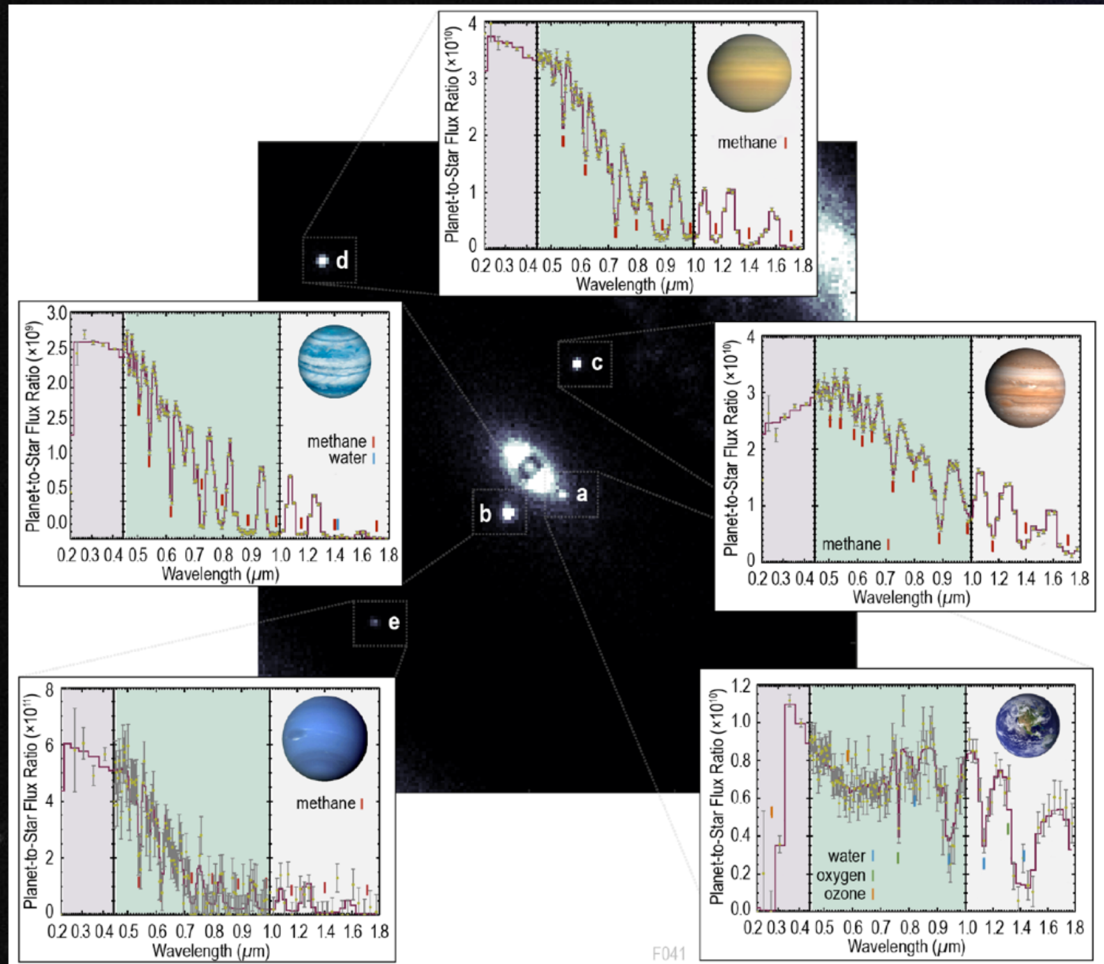
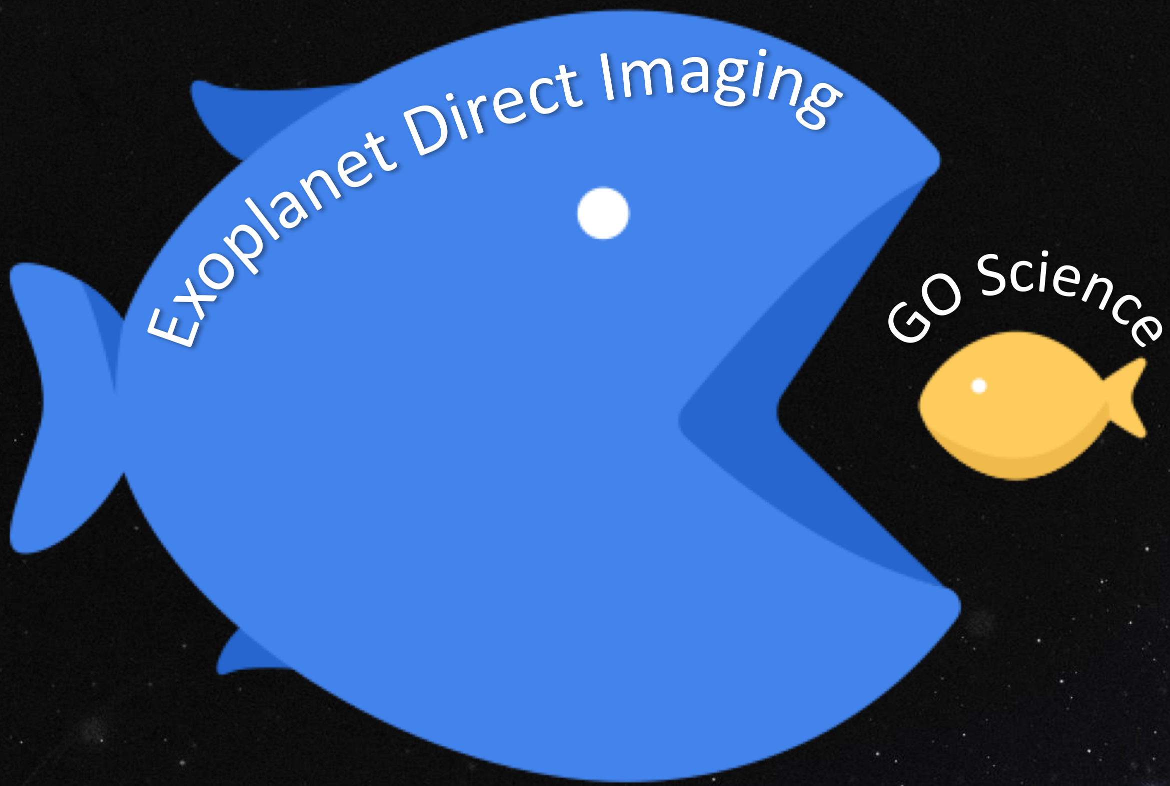
Mapping nearby planetary systems





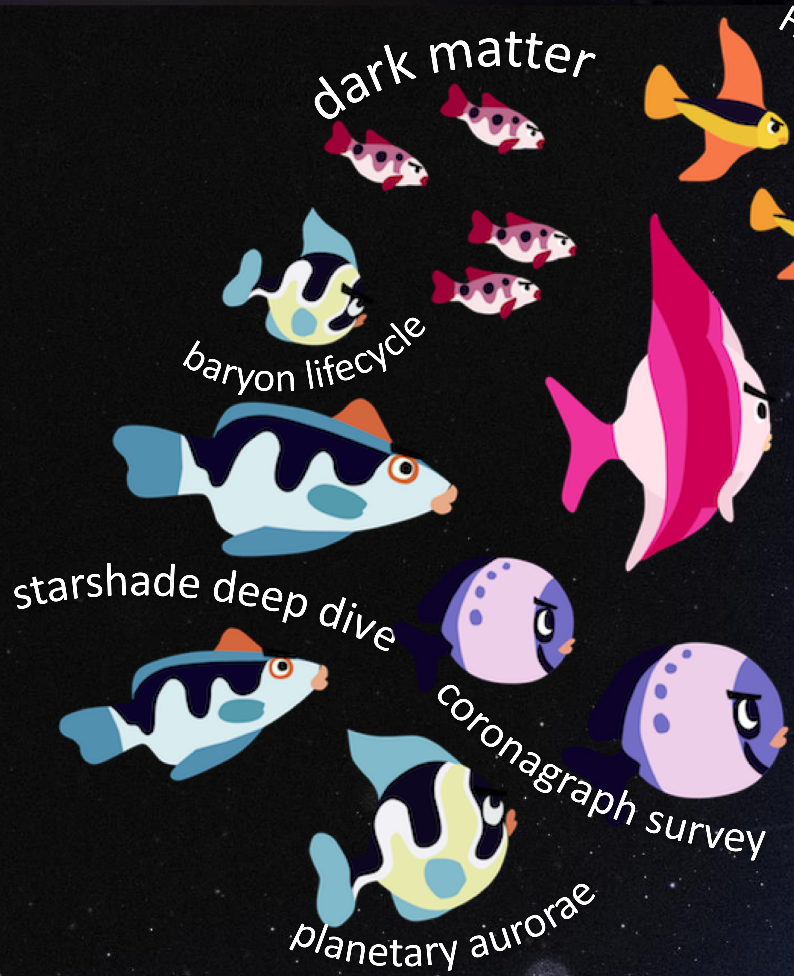
What you're thinking…



HabEx

NASA

The truth: 50% of HabEx's primary 5-year mission is dedicated to Guest Observer Science



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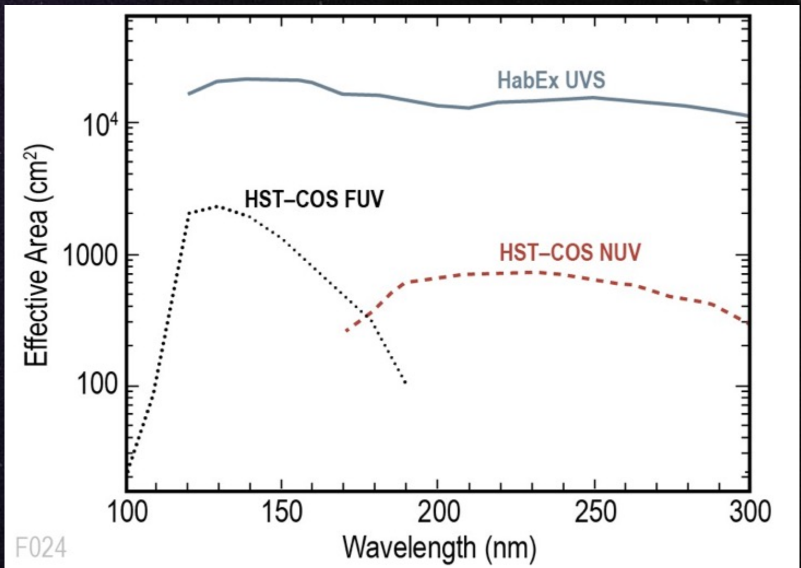
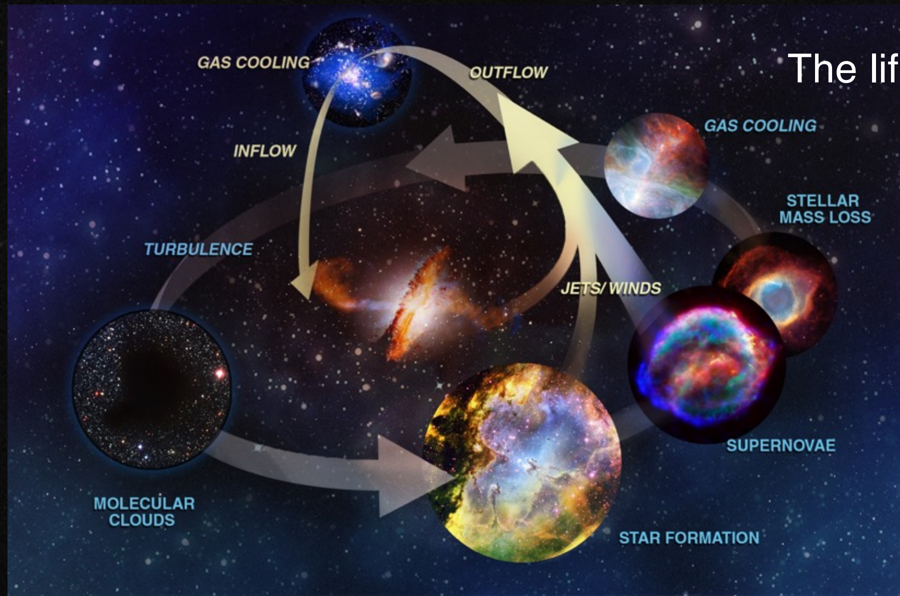
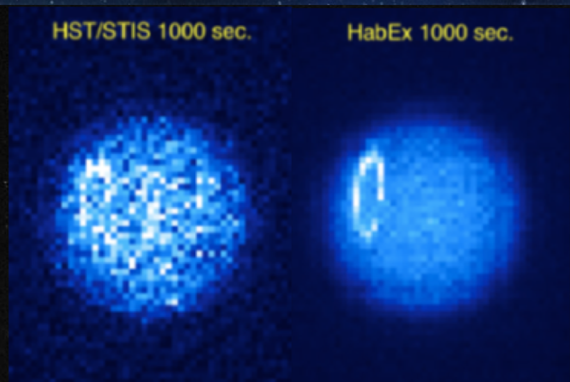
Future
Great Observatory



The lifecycle of baryons

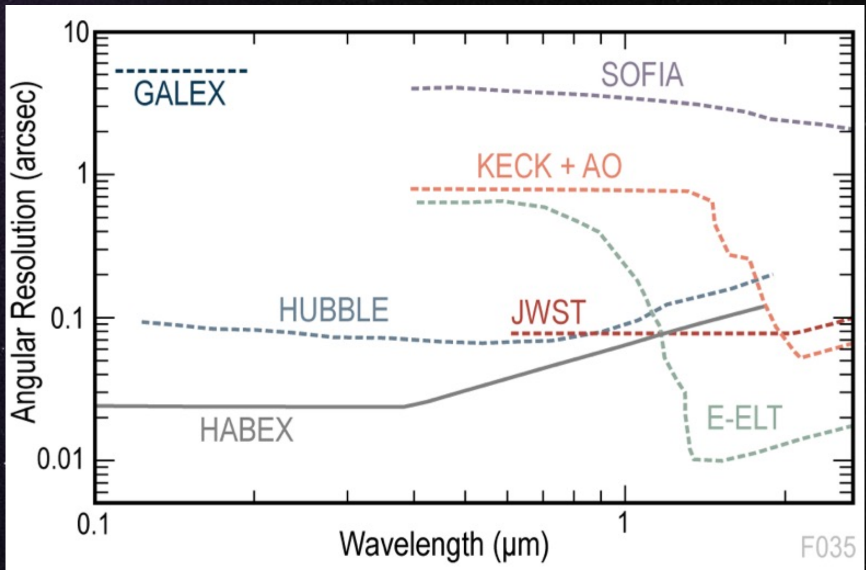


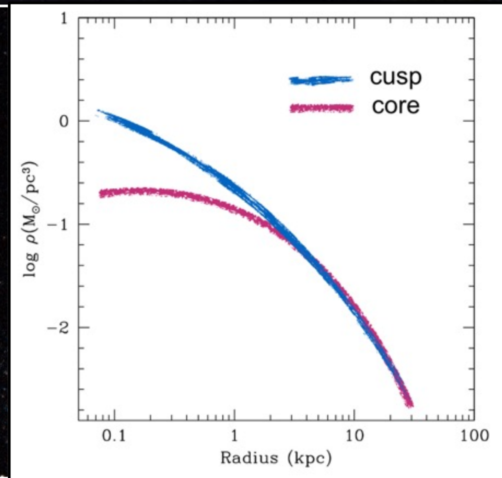


Solar System Aurorae

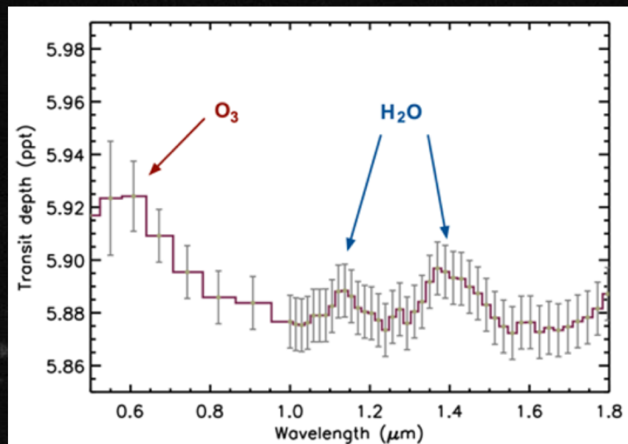
HabEx

Next Generation Great Observatory





Dark matter in dwarf galaxies



Exoplanet Transit Spectroscopy

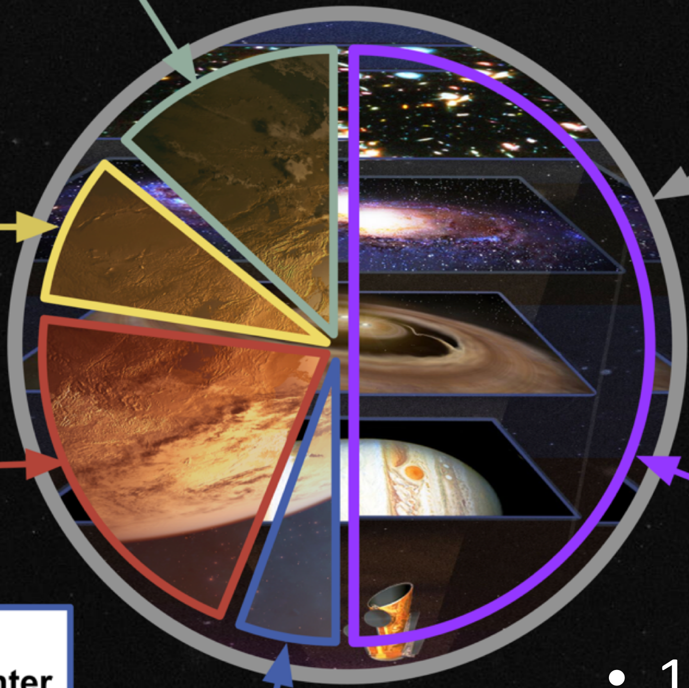
HabEx Observing Time Allocations

Broad Survey: non-exo-Earths
Starshade
0.5 y (~35 visits)

Broad Survey: exo-Earths
Starshade
0.65 y (~25 visits)

Broad Survey: exo-Earths
Coronagraph
1.1 y (~280 visits)

Deep Survey: exo-Earths & Fainter
Starshade
0.25 y (~25 visits)

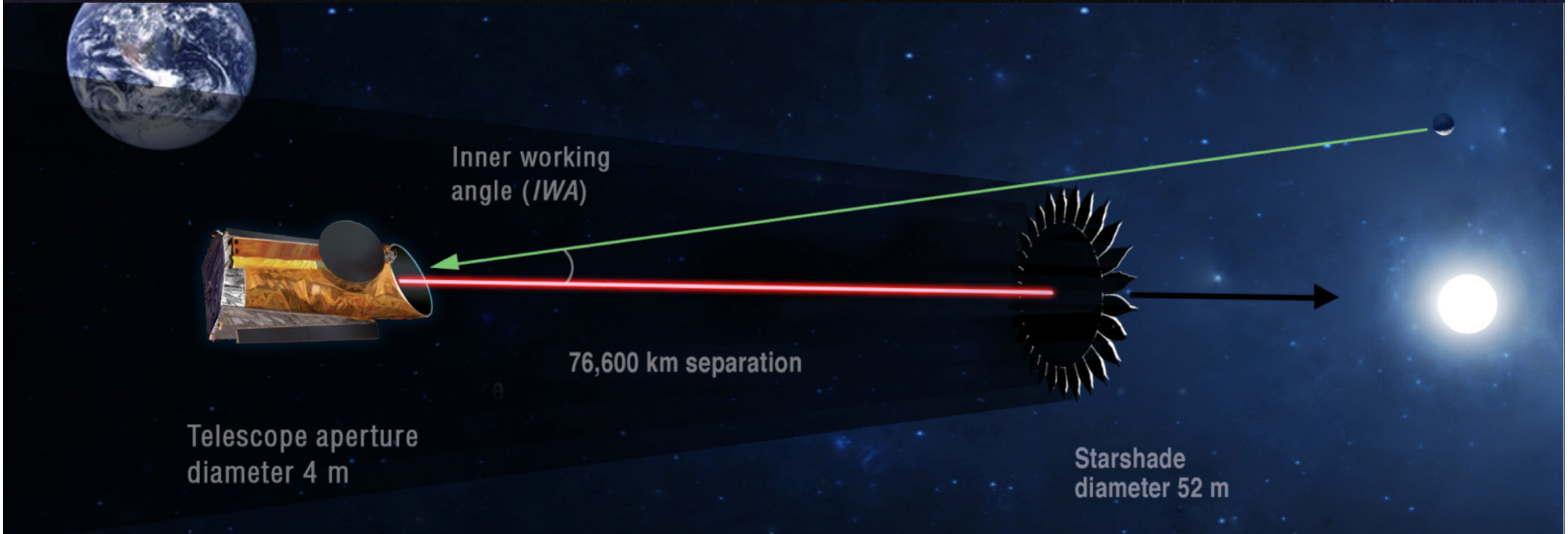


Parallel Observation Program
UVS & HWC
5 y

Guest Observer Program
All Instruments
2.5 y

- 100% Parallel Obs Time
- 50% GO Time
- 50% Exoplanet Survey Time

Baseline Architecture



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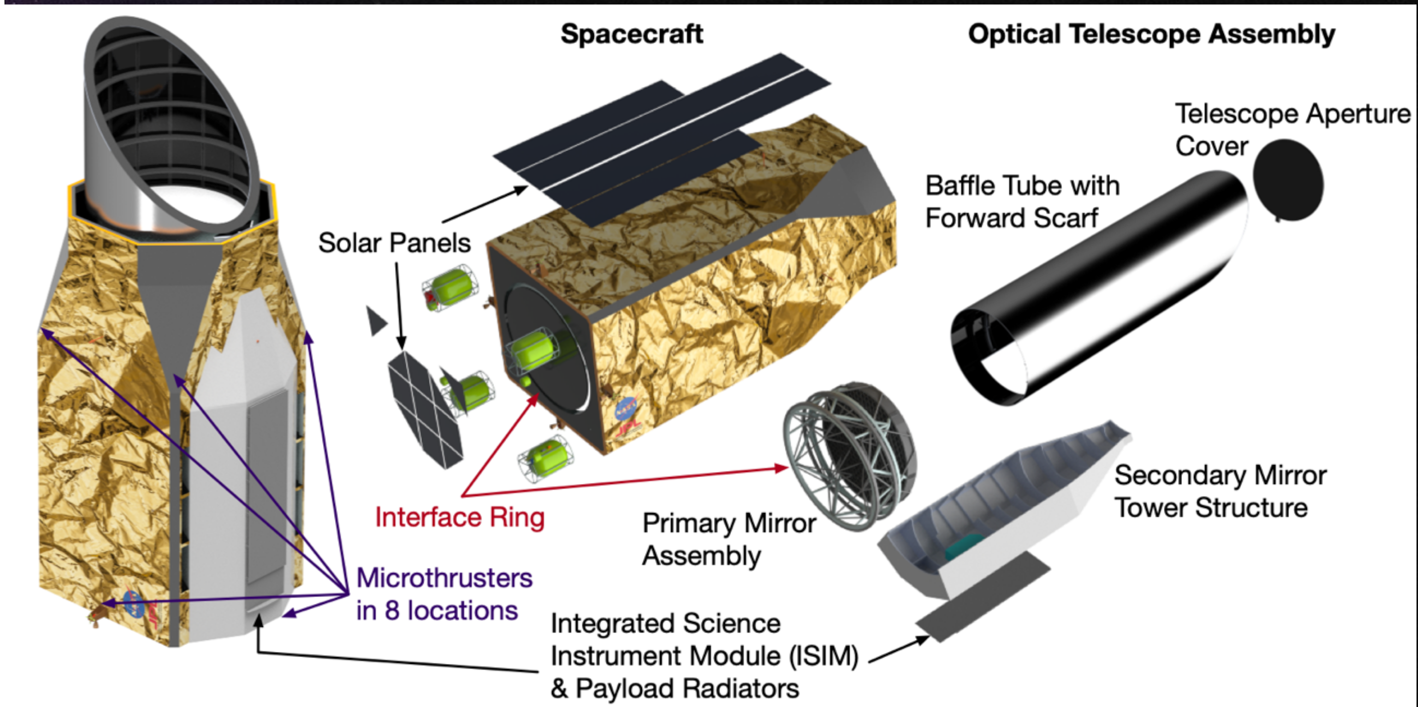
Baseline Architecture



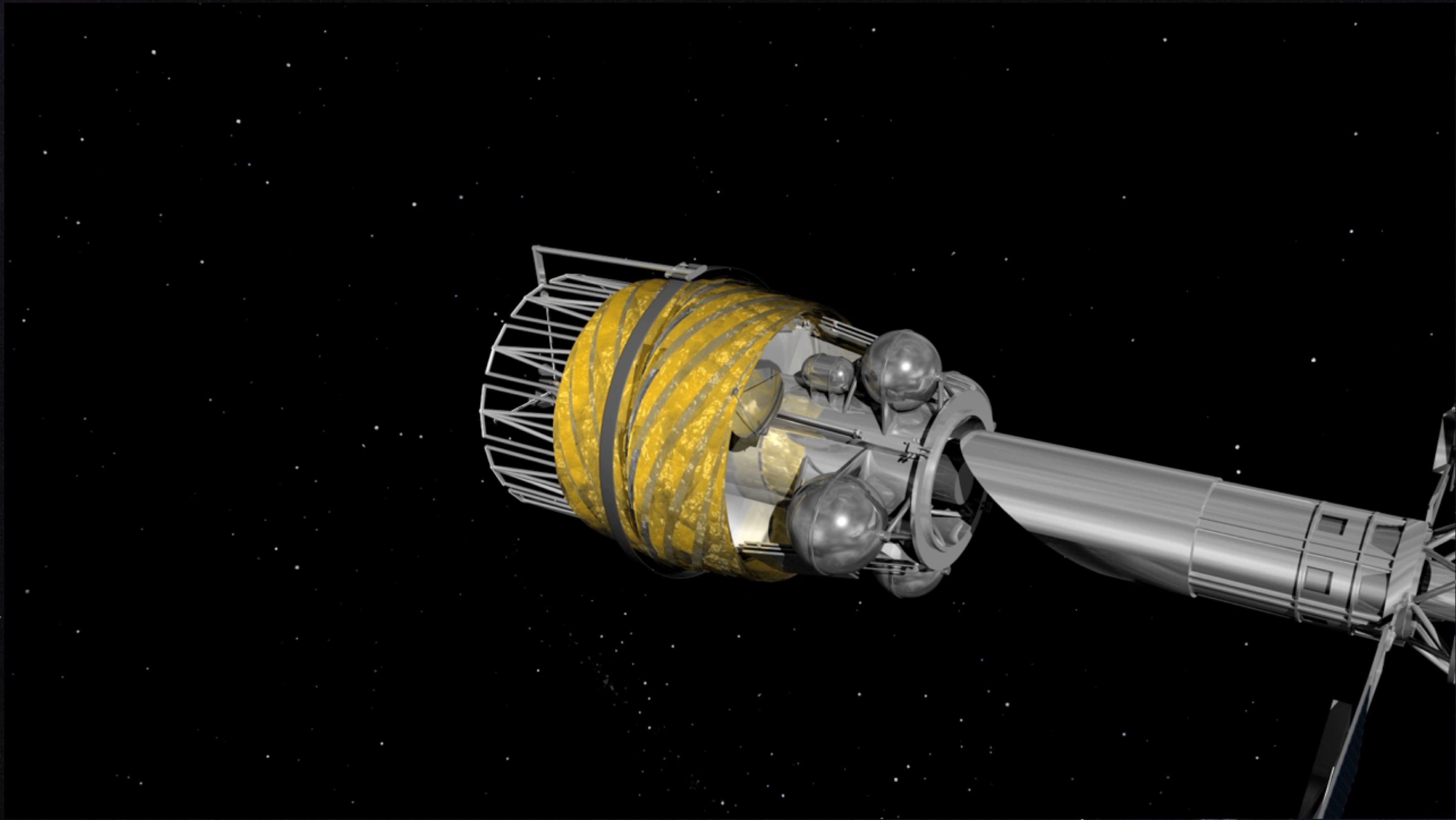
	Habitable Exoplanet Observatory (HabEx)
Mission Duration	5 years (10 years consumables)
Orbit	Earth-Sun L2 Halo
Aperture	4 m unobscured
Telescope Type	Off-axis three-mirror anastigmat
Primary Mirror	4 m monolith; glass-ceramic substrate; Al+MgF2 coating
Instruments (4)	Exoplanet science: Coronagraph, Starshade Observatory science: UV Spectrograph, Workhorse Camera
Attitude Control	Slewing: hydrazine thrusters; Pointing: microthrusters

	HST	HabEx
Aperture	2.4 m obscured	4.0 m unobscured
Diffraction Limit	500 nm	400 nm
Slew Rate (180 deg)	~30 min (max)	20 min (typical), 5 min (max)
Pointing Accuracy	5 mas (typical), 2 mas (best)	0.7 mas
Spatial Resolution	50 mas	25 mas
Effective Area* (@ 200nm)	700 cm^2	10,000 cm^2
Micro-shutters	No	Yes
Serviceable	Yes/Astronaut	Yes/Robotic

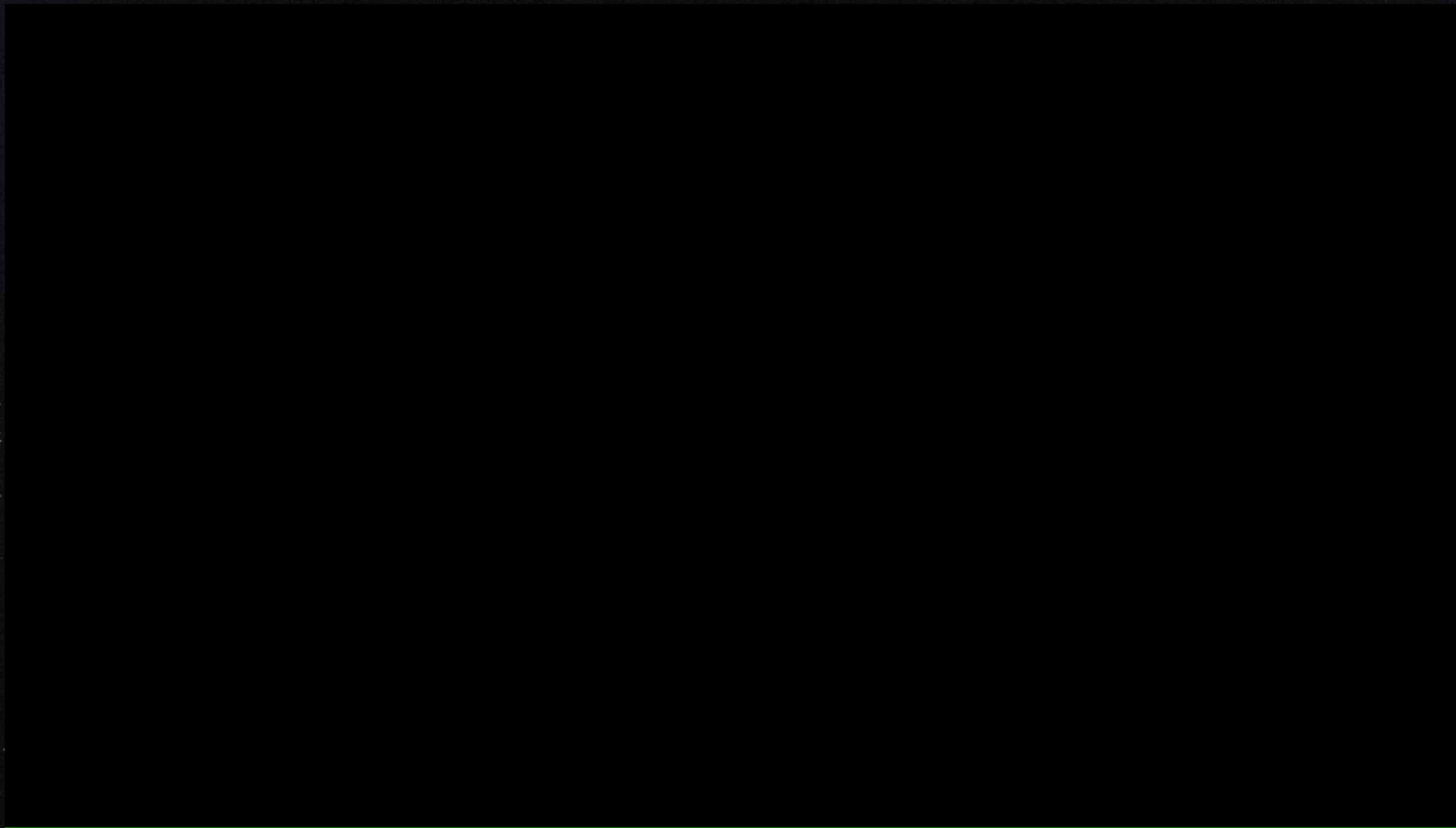
*Effective area is clear aperture multiplied by throughput and quantum efficiency

HabEx

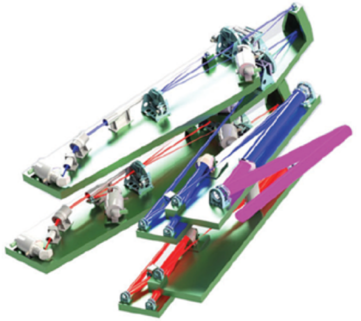
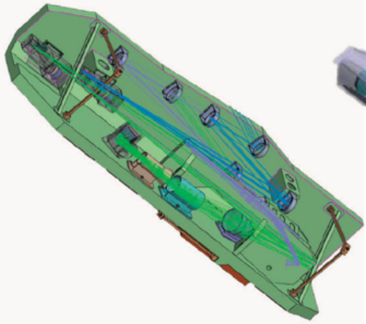
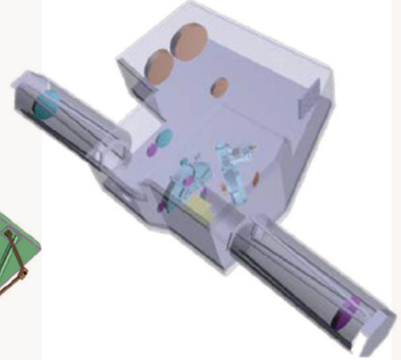
Starshade



Starshade

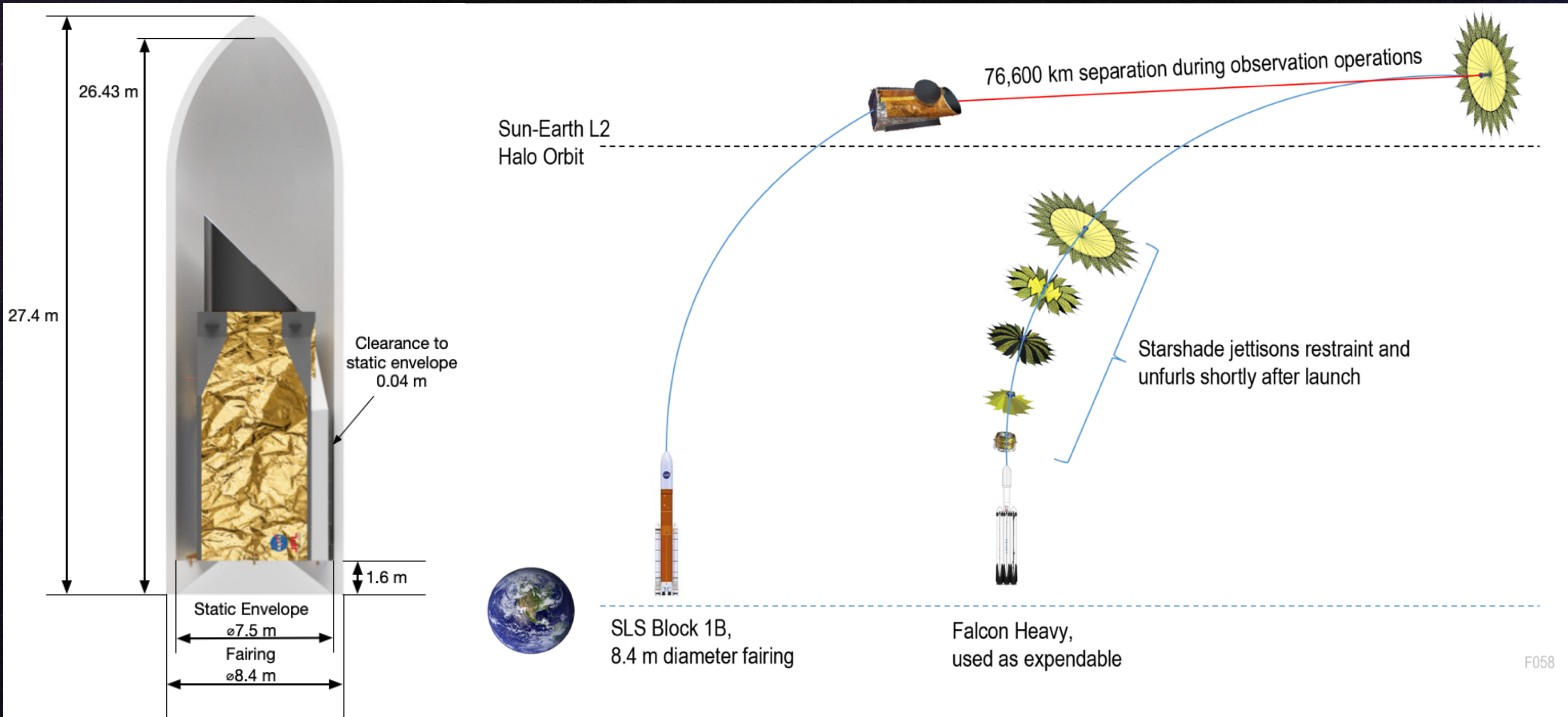


HabEx Instruments

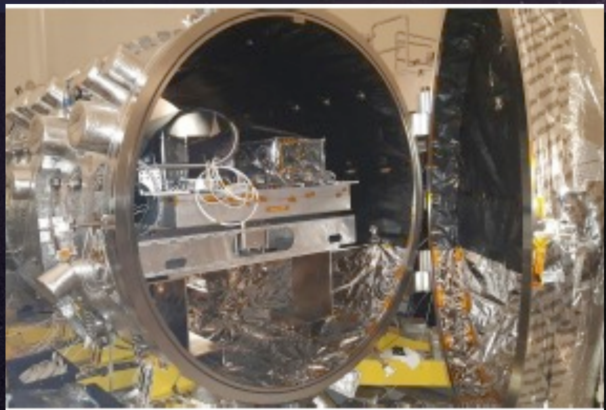
   

	Coronagraph (HCG)	Starshade (SSI)	Workhorse Camera (HWC)	UV Spectograph (UVS)
Purpose	Exoplanet imaging and characterization	Exoplanet imaging and characterization	Multipurpose, wide-field imaging camera and spectograph for observatory science	High-resolution, UV imaging and spectroscopy for observatory science
Instrument Type	Vector Vortex charge 6 coronagraph with: - Raw contrast: 2.5 x 10^{-10} at the IWA - Δ mag limit = 26.5 - 20% instantaneous bandwidth - Imager and spectograph	52 m diameter starshade occulter with: - 76,600 km separation (Visible) - Raw contrast: 1 x 10^{-10} at the IWA - Δ mag limit = 26.5 - 107% instantaneous bandwidth - Imager and spectograph	Imager and spectograph	High-resolution imager and spectrograph
Channels	Visible: 0.45–0.975 µm - Imager + IFS with R = 140 Near-IR: 0.975–1.8 µm - Imager + IFS with R = 40	UV: 0.2–0.45 µm - Imager + grism with R = 7 Visible: 0.45–0.975 µm - Imager + IFS with R = 140 Near-IR: 0.975–1.8 µm - Imager + IFS with R = 40	Visible: 0.37–0.975 µm - Imager + grism with R = 1,000 Near-IR: 0.95–1.8 µm - Imager + grism with R = 1,000	UV: 115–320 nm (with 115–370 nm available at $R \leq$ 1,000) R = 60,000; 25,000; 12,000; 6,000; 3,000; 1,000; 500; imaging
Field of View	IWA: 2.4 λ/D = 62 mas at 0.5 µm OWA: 32 λ/D = 830 mas at 0.5 µm	IWA: 58 mas at 0.3–1.0 µm OWA: 6 arcsec (Vis. broadband imaging) OWA: 1 arcsec (Visible IFS)	3 x 3 $arcmin^2$	3 x 3 $arcmin^2$
Features	64 x 64 deformable mirrors (2) Low-order wavefront sensing and control	Formation flying, sensing, and control	Microshutter array for multi-object spectroscopy - 2 x 2 array, 171 x 365 apertures	Microshutter array for multi-object spectroscopy - 2 x 2 array, 171 x 365 apertures

HabEx Launch

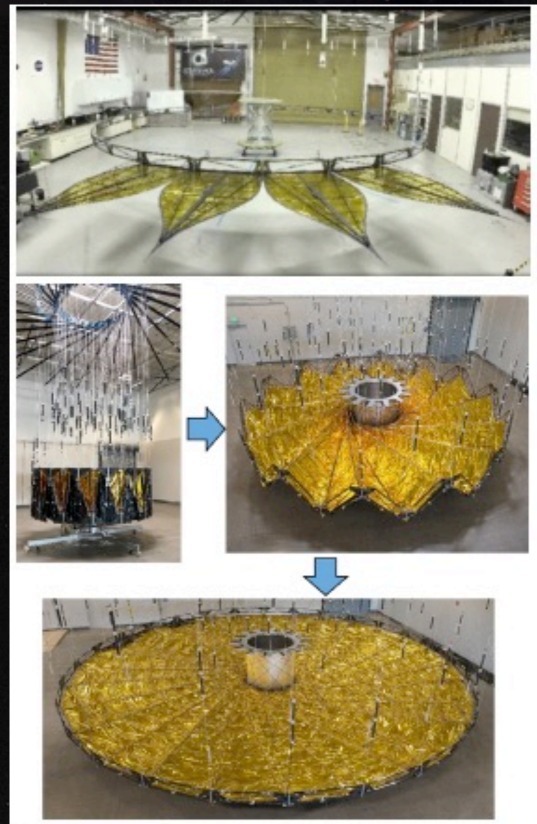


HabEx Enabling Technologies

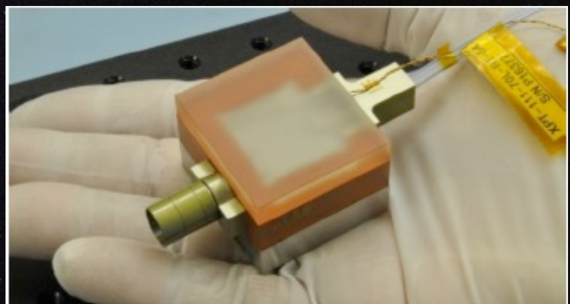


WFIRST Coronagraph Instrument Testbed

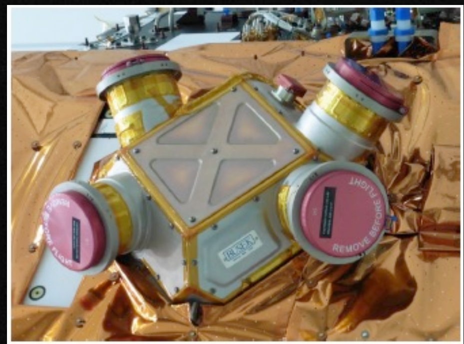
4.2m mirror for the Southern Astrophysical Research Telescope



Starshade 10m perimeter truss deployment tests



Planar lightwave circuit beam launcher for laser metrology



LISA-Pathfinder colloidal microthrusters

HabEx is the *only* study with all technologies at TRL 4 or higher.

HabEx

Architecture Trade Space

Telescope Aperture Diameter	Starlight Suppression Method: H (Hybrid)	S (Starshade-only)	C (Coronagraph-only)
4.0m	Planets: 186 Effective collecting area: 10,000 cm^2 Spatial resolution: 25 mas TRL-4 technologies: 13 Cost ($FY20): $6.8B	Planets: 144 Effective collecting area: 13,000 cm^2 Spatial resolution: 25 mas TRL-4 technologies: 9 Cost ($FY20): $5.7B	Planets: 119 Effective collecting area: 10,000 cm^2 Spatial resolution: 25 mas TRL-4 technologies: 10 Cost ($FY20): $4.8B
3.2m	Planets: 110 Effective collecting area: 6,400 cm^2 Spatial resolution: 31 mas TRL-4 technologies: 12 Cost ($FY20): $5.7B	Planets: 123 Effective collecting area: 8,200 cm^2 Spatial resolution: 31 mas TRL-4 technologies: 9 Cost ($FY20): $5.0B	Planets: 86 Effective collecting area: 6,400 cm^2 Spatial resolution: 31 mas TRL-4 technologies: 9 Cost ($FY20): $3.7B
2.4m	Planets: 79 Effective collecting area: 2,300 cm^2 Spatial resolution: 42 mas TRL-4 technologies: 11 Cost ($FY20): $4.8B	Planets: 69 Effective collecting area: 3,000 cm^2 Spatial resolution: 42 mas TRL-4 technologies: 8 Cost ($FY20): $4.0B	Planets: 28 Effective collecting area: 2,300 cm^2 Spatial resolution: 42 mas TRL-4 technologies: 8 Cost ($FY20): $3.1B

HabEx Architectures

HabEx Science Goals & Objectives			HabEx Mission Architectures								
			4H	4S	4C	3.2H	3.2S	3.2C	2.4H	2.4S	2.4C
Habitable Exoplanets	O1	Exo-Earth candidates around nearby sunlike stars?	Green	Green	Green	Green	Yellow	Green	Yellow	Orange	Orange
	O2	Water vapor in rocky exoplanet atmospheres?	Green	Green	Green	Green	Yellow	Yellow	Yellow	Orange	Orange
	O3	Biosignatures in rocky exoplanet atmosphere?	Green	Green	Yellow	Green	Yellow	Yellow	Yellow	Orange	Orange
	O4	Surface liquid water on rocky exoplanets?	Green	Green	Yellow	Green	Yellow	Orange	Yellow	Orange	Orange
Exoplanetary Systems	O5	Architectures of nearby planetary systems?	Green	Orange	Yellow	Green	Orange	Yellow	Yellow	Orange	Orange
	O6	Exoplanet atmospheric variations in nearby systems?	Green	Yellow	Yellow	Green	Orange	Orange	Yellow	Orange	Orange
	O7	Water transport mechanisms in nearby planetary systems?	Green	Green	Yellow	Green	Yellow	Yellow	Yellow	Orange	Orange
	O8	Debris disk architectures in nearby planetary systems?	Green	Green	Yellow	Green	Green	Yellow	Green	Green	Yellow
Observatory Science	O9	LIfecycle of baryons?	Green	Green	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
	O10	Sources of reionization?	Green	Green	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
	O11	Origins of the elements?	Green	Green	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
	O12	Discrepancies in measurements of the cosmic expansion rate?	Green	Green	Green	Green	Green	Green	Yellow	Yellow	Yellow
	O13	The nature of dark matter?	Green	Green	Green	Yellow	Yellow	Yellow	Orange	Orange	Orange
	O14	Formation and evolution of globular clusters?	Green	Green	Green	Green	Green	Green	Yellow	Yellow	Yellow
	O15	Habitable conditions on rocky planets around M-dwarfs?	Green	Green	Green	Yellow	Yellow	Yellow	Orange	Orange	Orange
	O16	Mechanisms responsible for transition disk architectures?	Green	Yellow	Green	Green	Yellow	Green	Yellow	Yellow	Yellow
	O17	Physics driving star-planet interactions, *e.g.* auroral activity?	Green	Green	Green	Green	Green	Green	Green	Green	Green

All architectures include the HWC and UVS
H: Hybrid – Starshade and Coronagraph
C: Coronagraph
S: Starshade

Green: Meets baseline requirements
Yellow: Meets threshold requirements
Orange: Below threshold requirements

HabEx

- HabEx briefing to the Decadal Survey Nov 19/20

- Decadal Survey recommendations released in 2021

- What would YOU do with HabEx?!

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