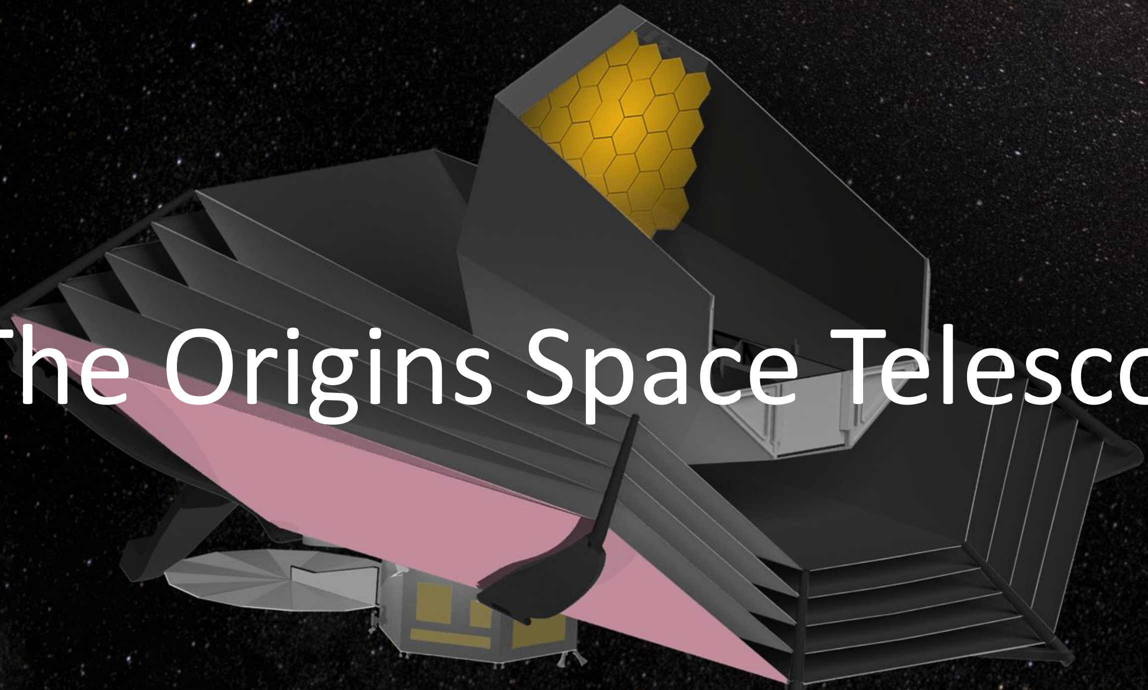
The Origins Space Telescope (OST)



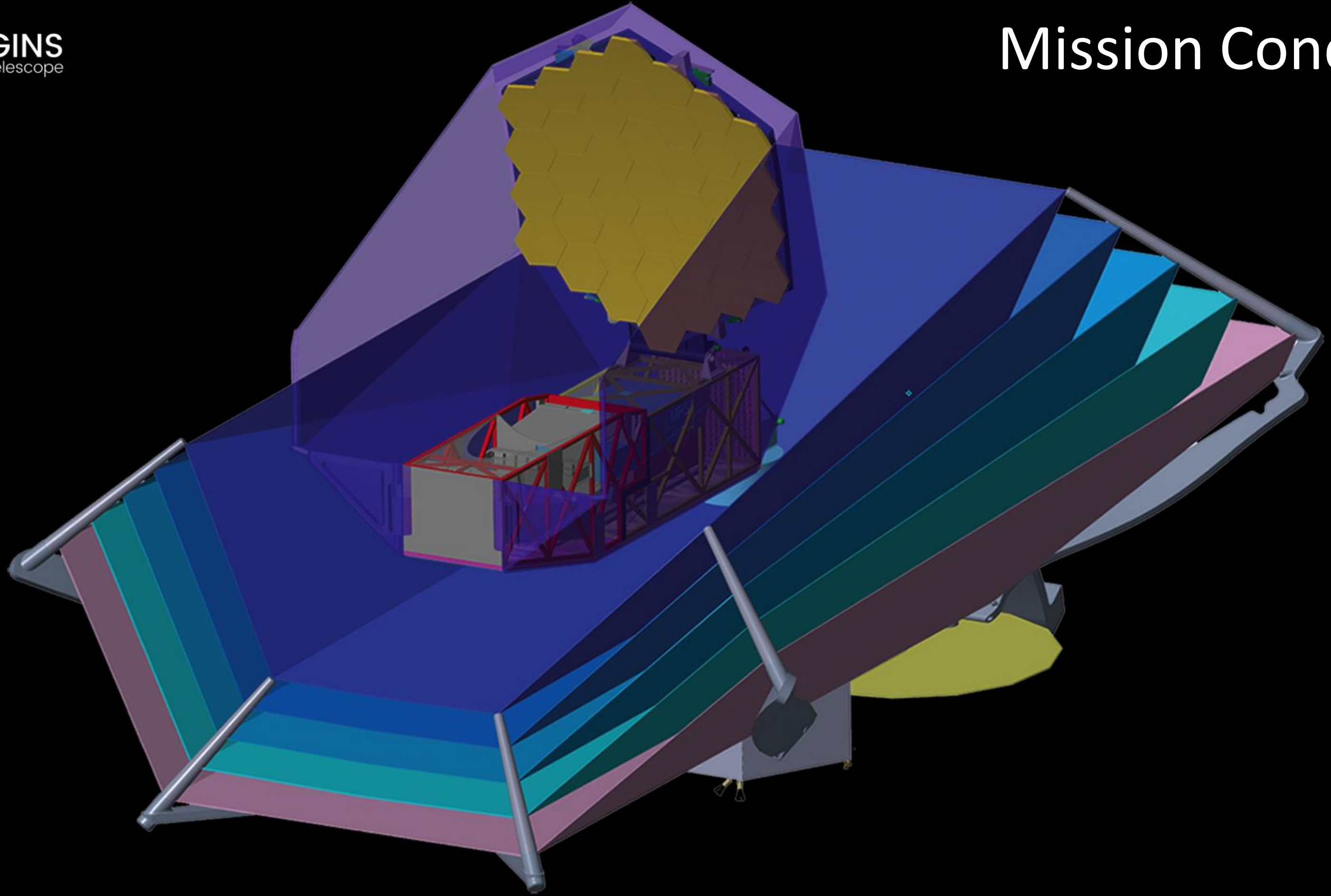
Margaret Meixner
Community co-chair for OST
STScI/JHU/NASA Goddard

The OST NASA Decadal Study

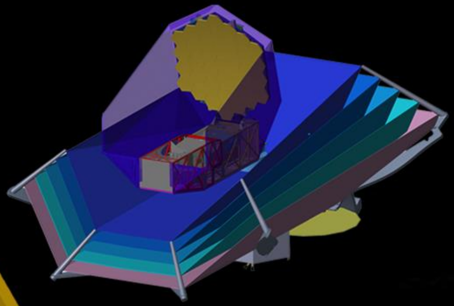
- NASA Astrophysics Roadmap Enduring Quests, Daring Visions: formerly known as Far-Infrared Surveyor
- Origins Space Telescope: 5-660 μm
- Goal: large general astronomy mission with exciting science that is technologically executable in 2030s
- Both Science Definition & Technological Implementation important
- OST study has two concepts:
  - Mission Concept 1, completed, described here
  - Mission Concept 2, started – optimization


The OST Study Team
Full team list: asd.gsfc.nasa.gov/firs/

Mission Concept 1

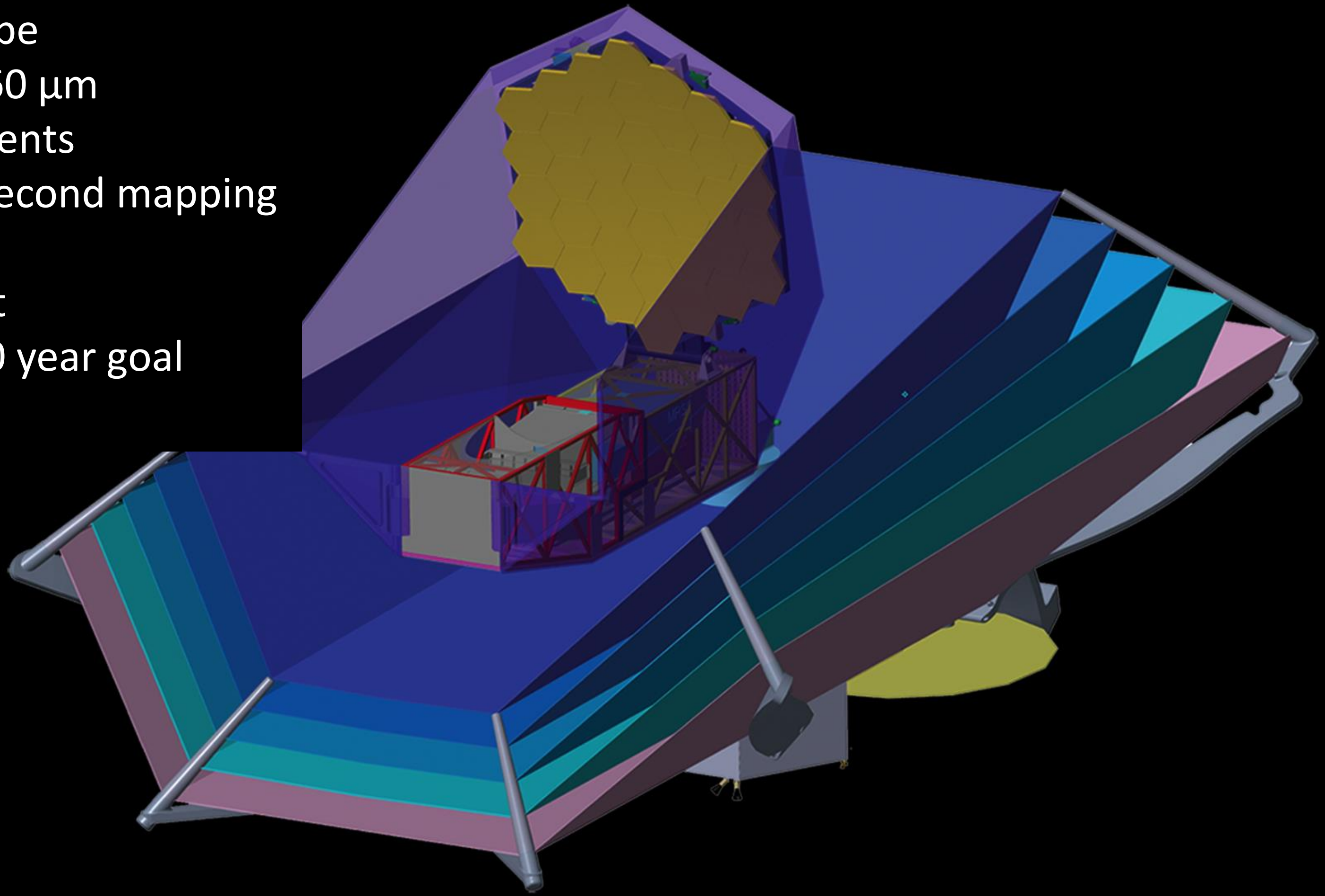


ORIGINS Space Telescope

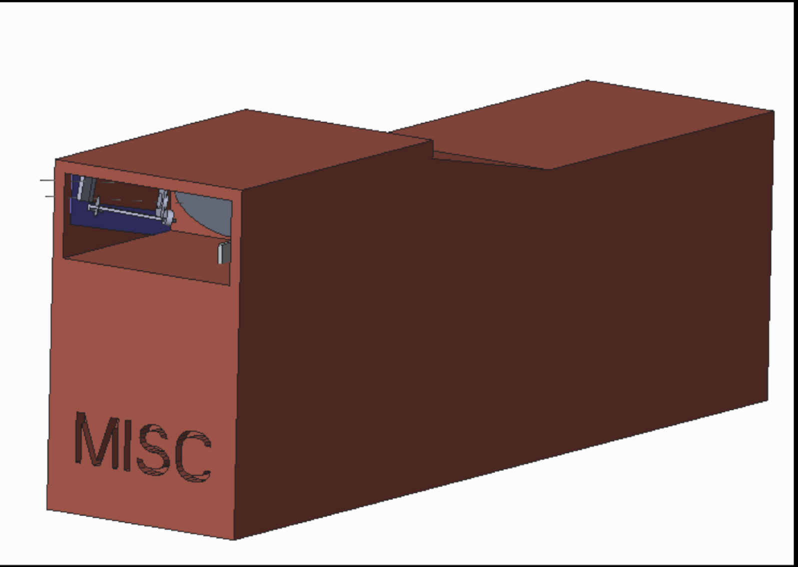


9.1 m primary mirror

- 9.1 m off-axis primary mirror
- Cold (4 K) telescope
- Wavelengths 5-660 µm
- 5 science instruments
- 100 arcseconds/second mapping
- Launch 2030s
- Sun-Earth L2 orbit
- 5 year lifetime, 10 year goal

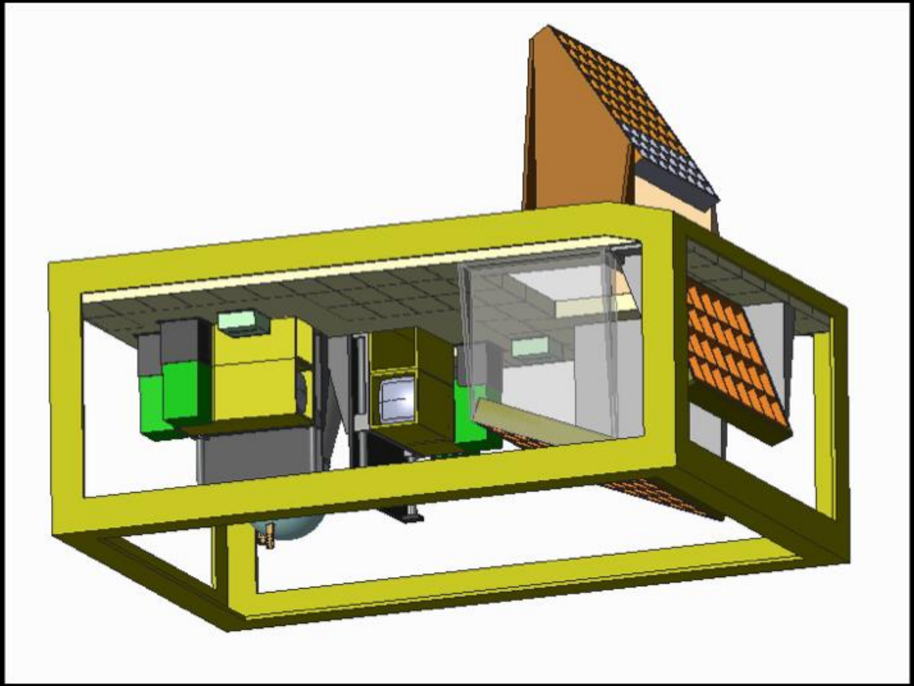


MISC: Mid-Infrared Imager, Spectrometer, Coronagraph



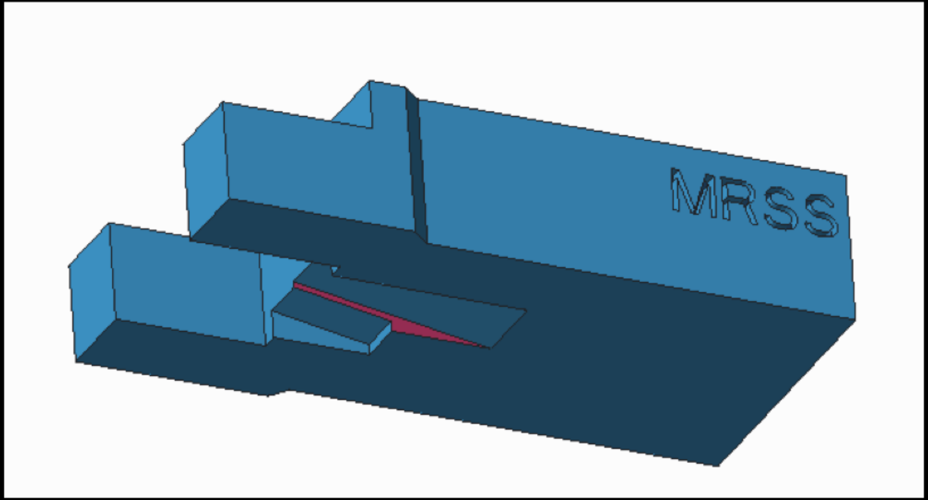
- 5-38 μm
- $\Delta\lambda/\lambda$ ~ 15, 300, 1200, 10^4
- Imaging
- Spectroscopy
- Coronagraphy 10^6 contrast
- Transit spectrometer <10 ppm stability

FIP: Far-Infrared Imager and Polarimeter



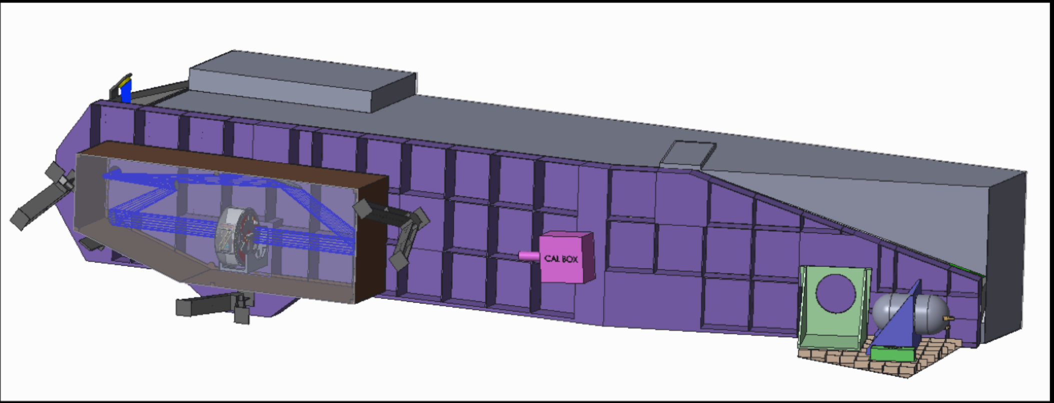
- 40, 80, 120, 240 μm
- $\Delta\lambda/\lambda \sim 15$
- 4 band Simultaneous Imaging
- Differential Polarimetric Imaging

MRSS: Medium Resolution Survey Spectrometer



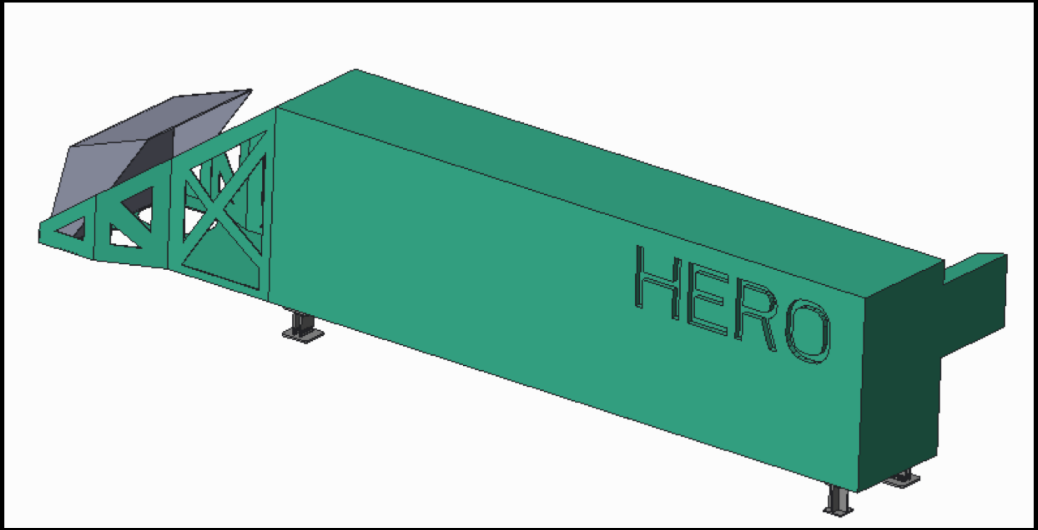
- 30-660 μm
- $\Delta\lambda/\lambda$ ~ 500, $4x10^4$
- Multi-band Spectroscopy
- Survey
- Single Target

HRS: High Resolution Spectrometer

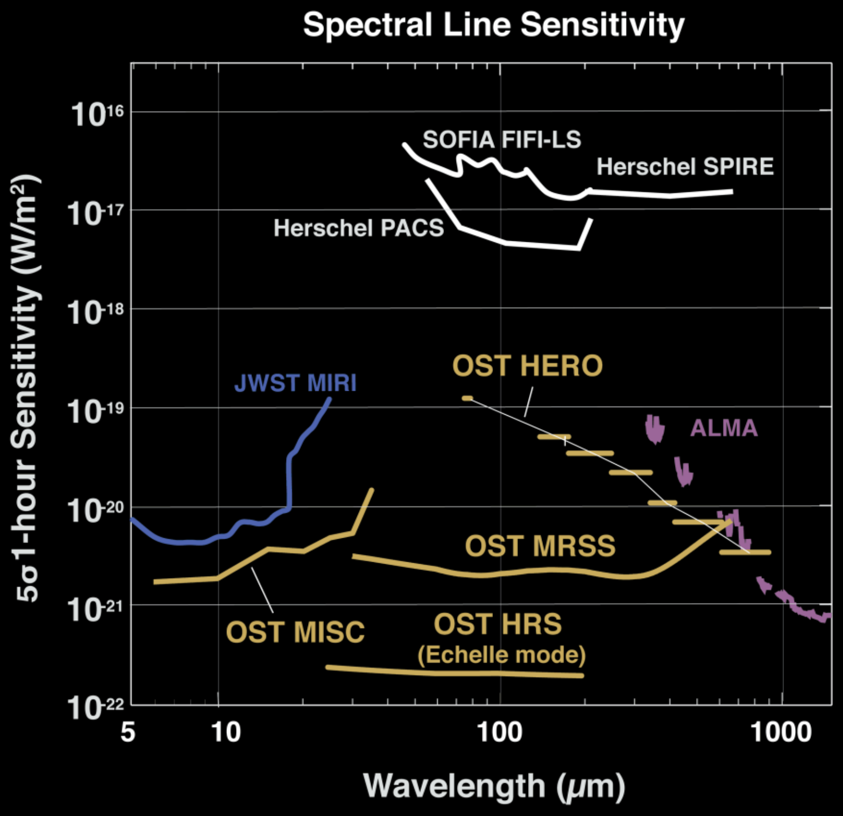


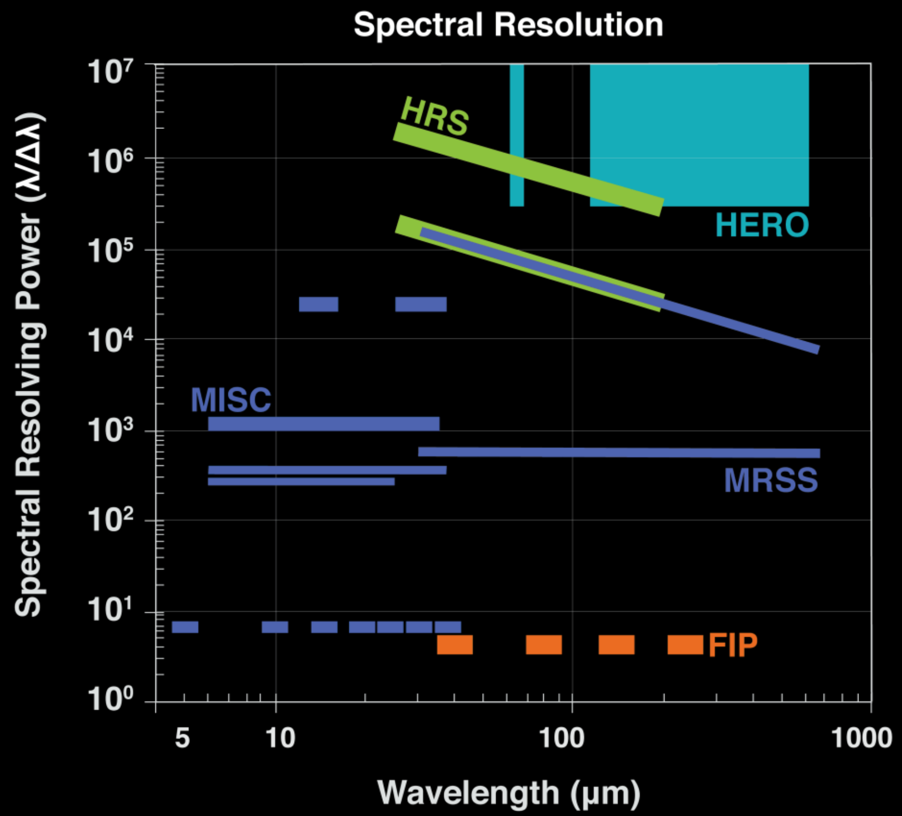
- 25-200 μm
- $\Delta\lambda/\lambda \sim 5x10^4, 5x10^5$
- Spectroscopy
- Single Target
- Small maps

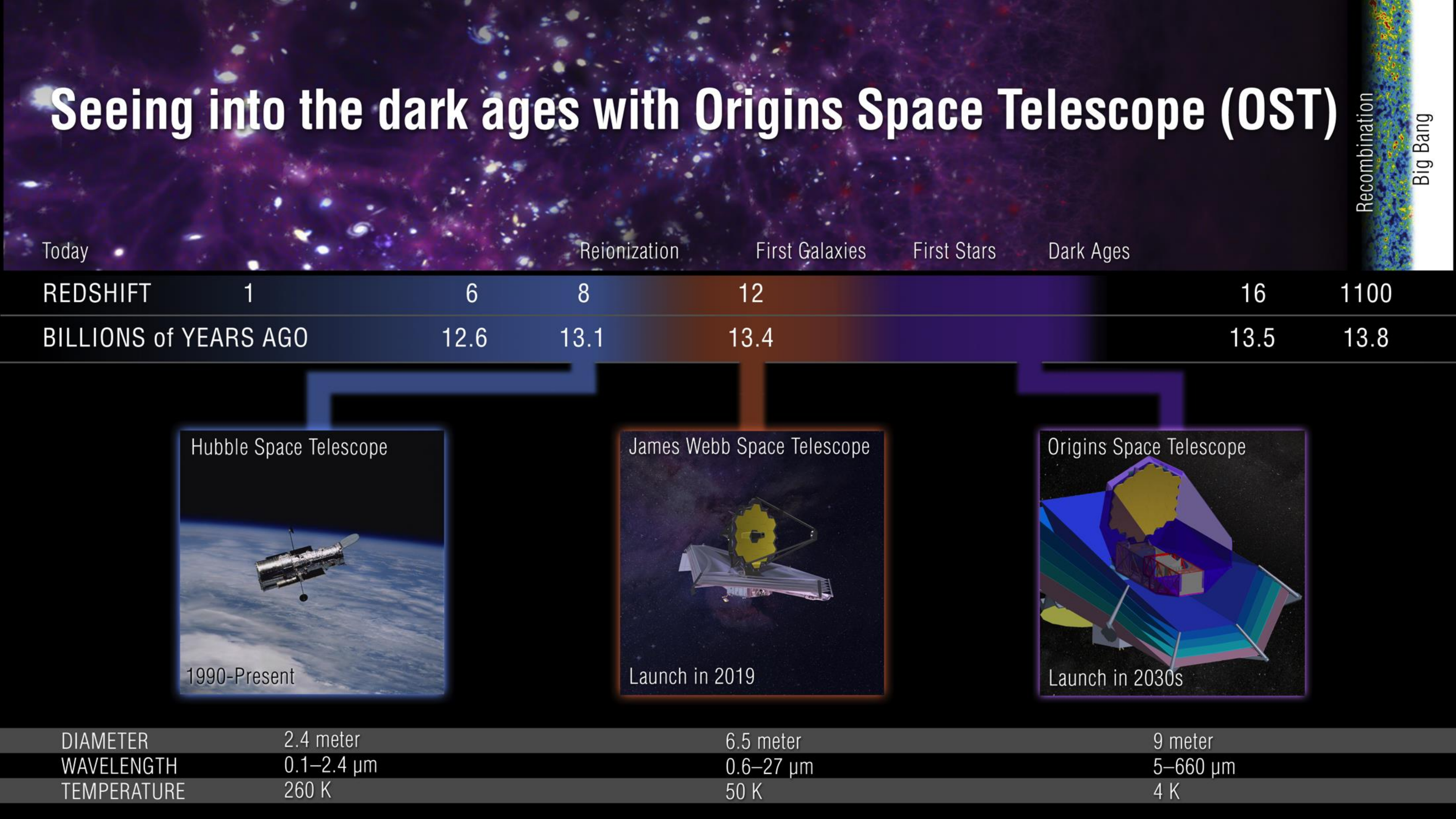
HERO: Heterodyne Receiver for OST



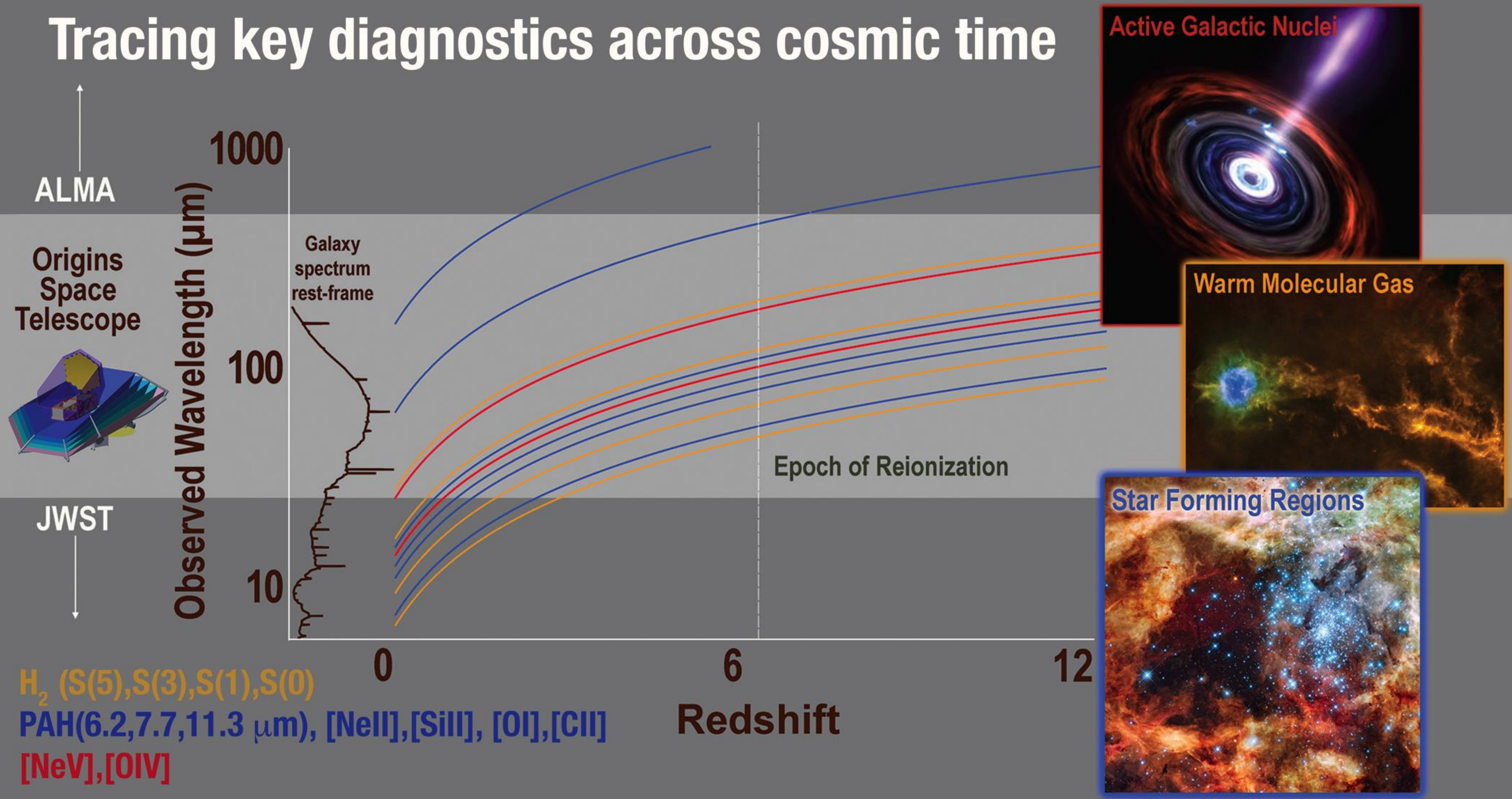
- 63-66, 111-610 μm
- $\Delta\lambda/\lambda \sim 10^7$
- Multi-beam Spectroscopy
- Small maps


Spectral Line Sensitivity
5σ1-hour Sensitivity (W/m²)
10¹⁶
10⁻¹⁷
10⁻¹⁸
10⁻¹⁹
10⁻²⁰
10⁻²¹
10⁻²²
SOFIA FIFI-LS
Herschel SPIRE
Herschel PACS
OST HERO
JWST MIRI
ALMA
OST MRSS
OST MISC
OST HRS
(Echelle mode)
5
10
100
1000
Wavelength (μm)


Spectral Resolution
Spectral Resolving Power (λ/Δλ)
10⁷
10⁶
10⁵
10⁴
10³
10²
10¹
10⁰
HRS
HERO
MISC
MRSS
FIP
5
10
100
1000
Wavelength (μm)


Seeing into the dark ages with Origins Space Telescope (OST)
Recombination
Big Bang
Today
Reionization
First Galaxies
First Stars
Dark Ages
REDSHIFT 1 6 8 12 16 1100
BILLIONS of YEARS AGO 12.6 13.1 13.4 13.5 13.8
Hubble Space Telescope
1990-Present
James Webb Space Telescope
Launch in 2019
Origins Space Telescope
Launch in 2030s
DIAMETER 2.4 meter 6.5 meter 9 meter
WAVELENGTH 0.1–2.4 μm 0.6–27 μm 5–660 μm
TEMPERATURE 260 K 50 K 4 K

Tracing key diagnostics across cosmic time



Species	Wavelength [µm]	f (M82)	f (Arp220)	Diagnostic Utility
		Ionized Gas Fine Structure Lines		
Ne V	24.3			Unambiguously AGN
O IV	25.9, 54.9			Primarily AGN
S IV	10.5	2.1 (-5)		
Ne II	12.3	1.2 (-3)	7.5 (-5)	Probes gas density and
Ne III	15.6, 36.0	2.05 (-4)		UV field hardness in
S III	18.7, 33.5	1.0 (-3)	7.3 (-5)	star formation HII
Ar III	21.83	9.1 (-6)		regions.
O III	51.8, 88.4	1.3 (-3)		
N III	57.3	4.2 (-4)		
N II	122, 205	2.1 (-4)		Diffuse HII regions
		Neutral Gas Fine Structure Lines		
Fe II	26.0			Density and temperature probes
Si II	34.8	1.1 (-3)	7.7 (-5)	of photodissociated-neutral
O I	63.1, 145	2.2 (-3)	6.8 (-5) (abs)	gas interface between HII
C II	158	1.6 (-3)	1.3 (-4)	regions and molecular clouds.
		Molecular Lines		
H_2	9.66, 12.3, 17.0, 28.2	2 (-5)	3 (-5)	Coolants of first collapse
CH	149		4 (-5)	Ground state absorbtion:
OH	34.6, 53.3, 79.1, 119	2 (-6)	2 (-4) (abs)	gives column and abundance.
OH	98.7, 163		5 (-5)	Emission: gas coolants, constrain
H_2O	73.5, 90, 101, 107, 180		5 (-5)	temperature, density of warm
CO	325, 372, 434, 520	3 (-6)	1 (-5)	(50K < T < 500 K) mol. gas

Diagnostic Spectral Lines
In 10-100 µm probe
Star forming ISM:

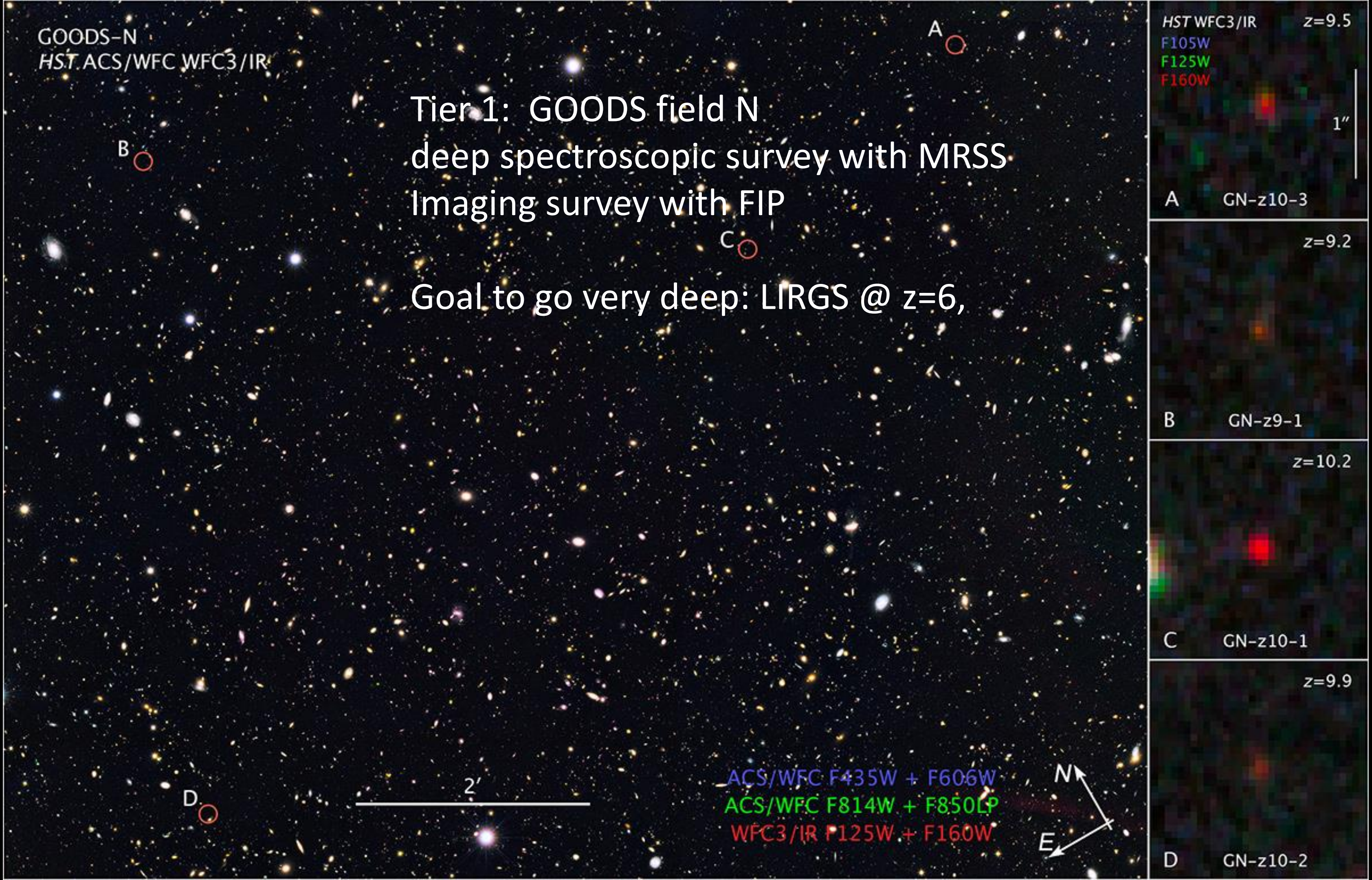
-ionized gas

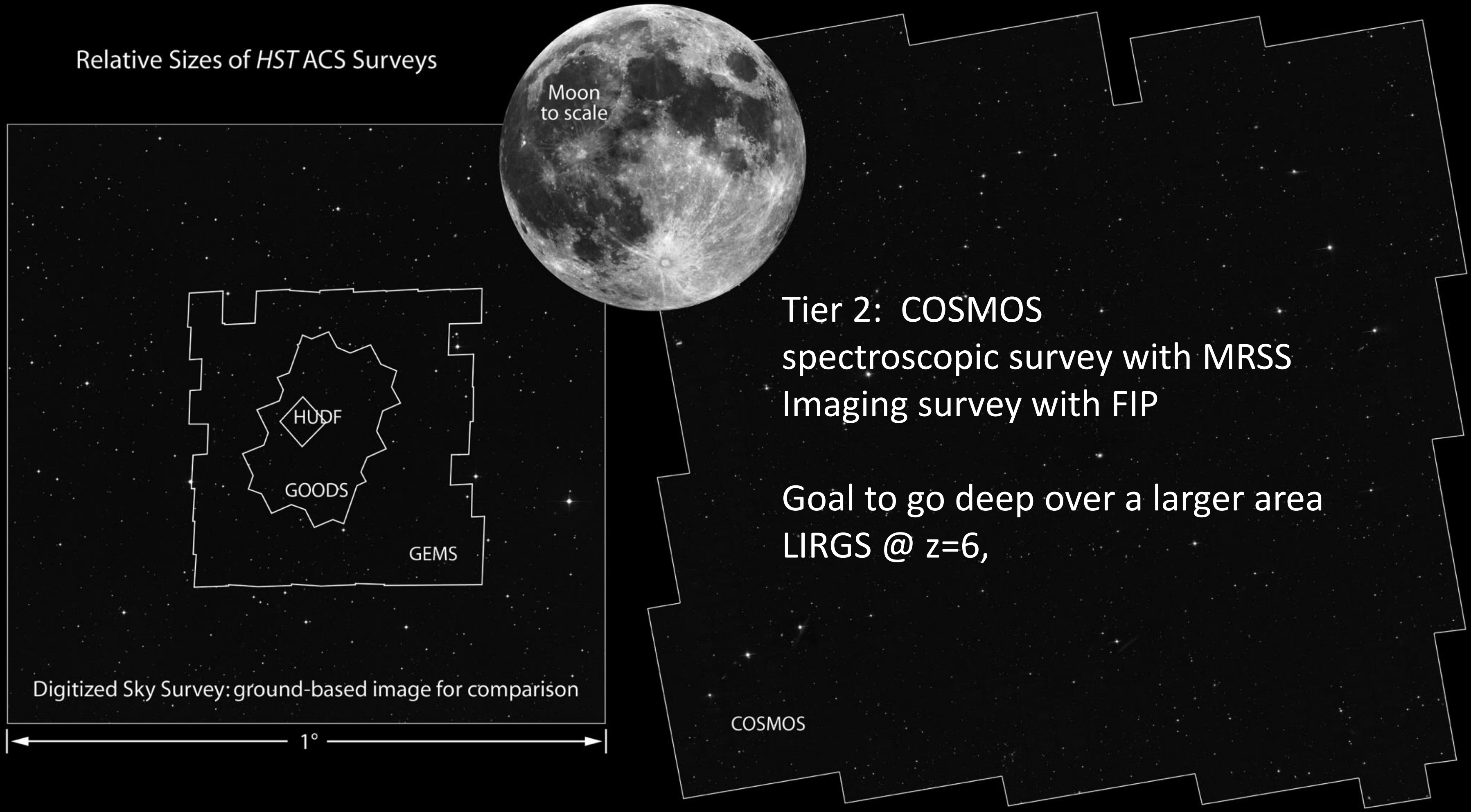
-atomic neutral gas

-molecular gas

Tier 1: GOODS field N
deep spectroscopic survey with MRSS
Imaging survey with FIP

Goal to go very deep: LIRGS @ z=6,



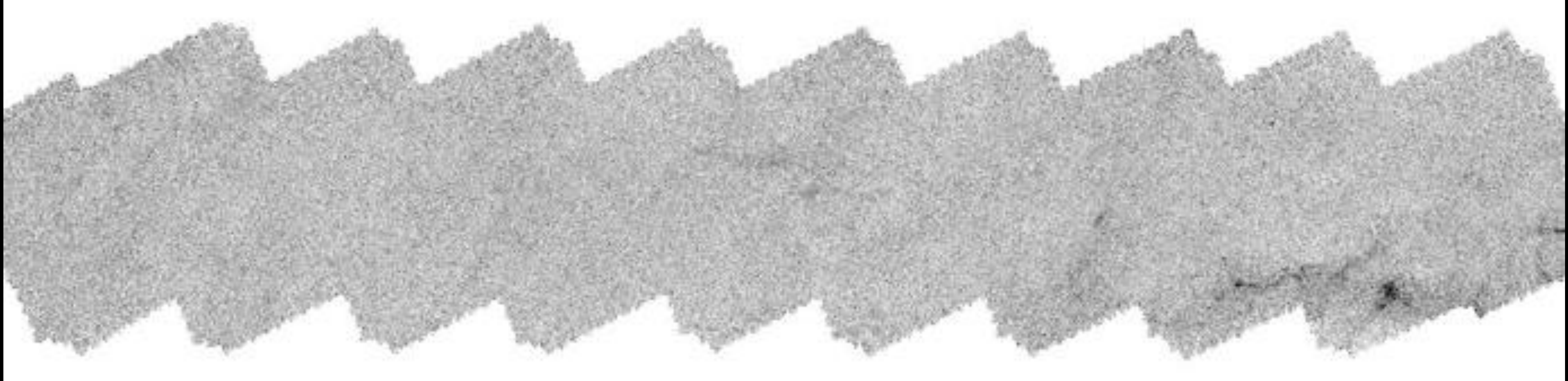

Relative Sizes of *HST* ACS Surveys
Moon
to scale
HUDF
GOODS
GEMS
Digitized Sky Survey: ground-based image for comparison
1°
COSMOS
Tier 2: COSMOS
spectroscopic survey with MRSS
Imaging survey with FIP
Goal to go deep over a larger area
LIRGS @ z=6,

Tier 3: Stripe 82

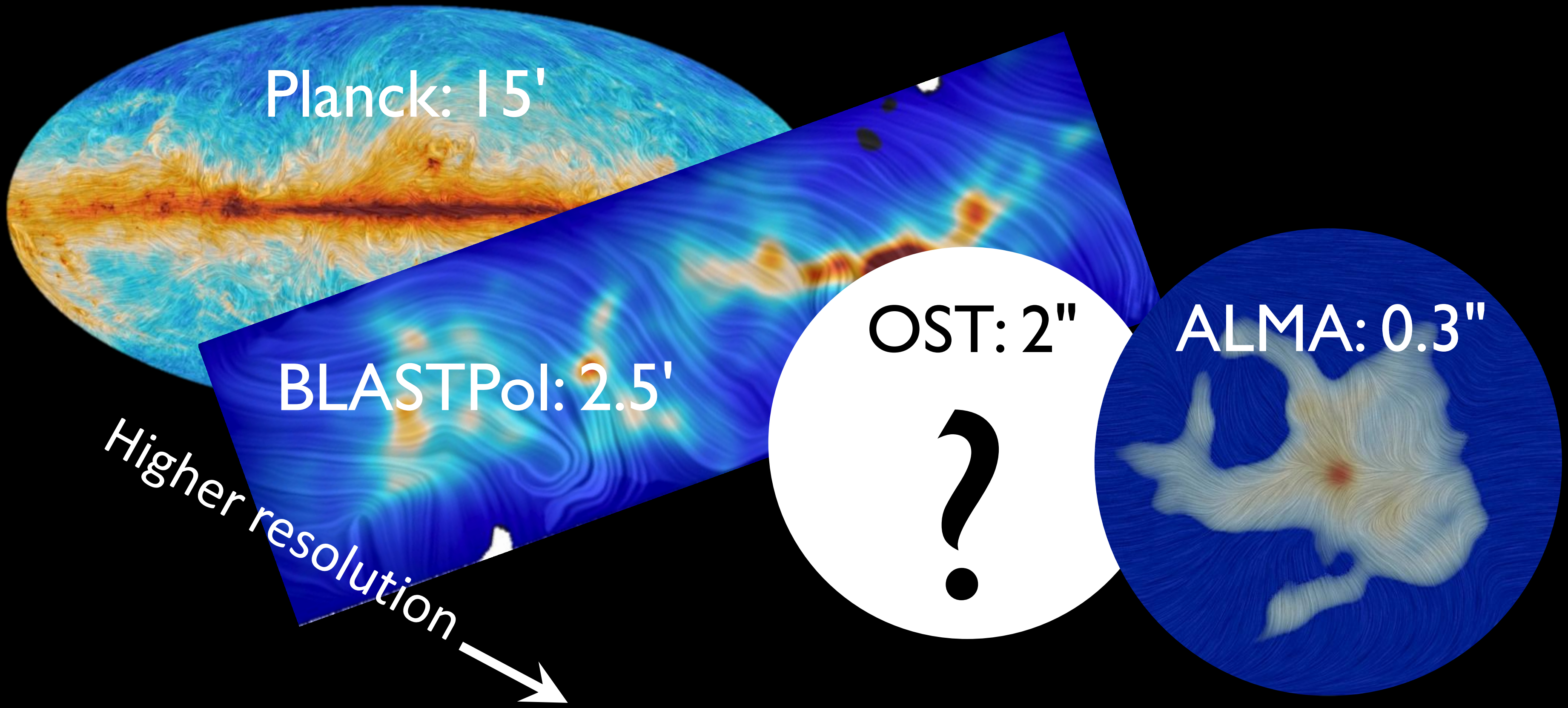
spectroscopic survey with MRSS

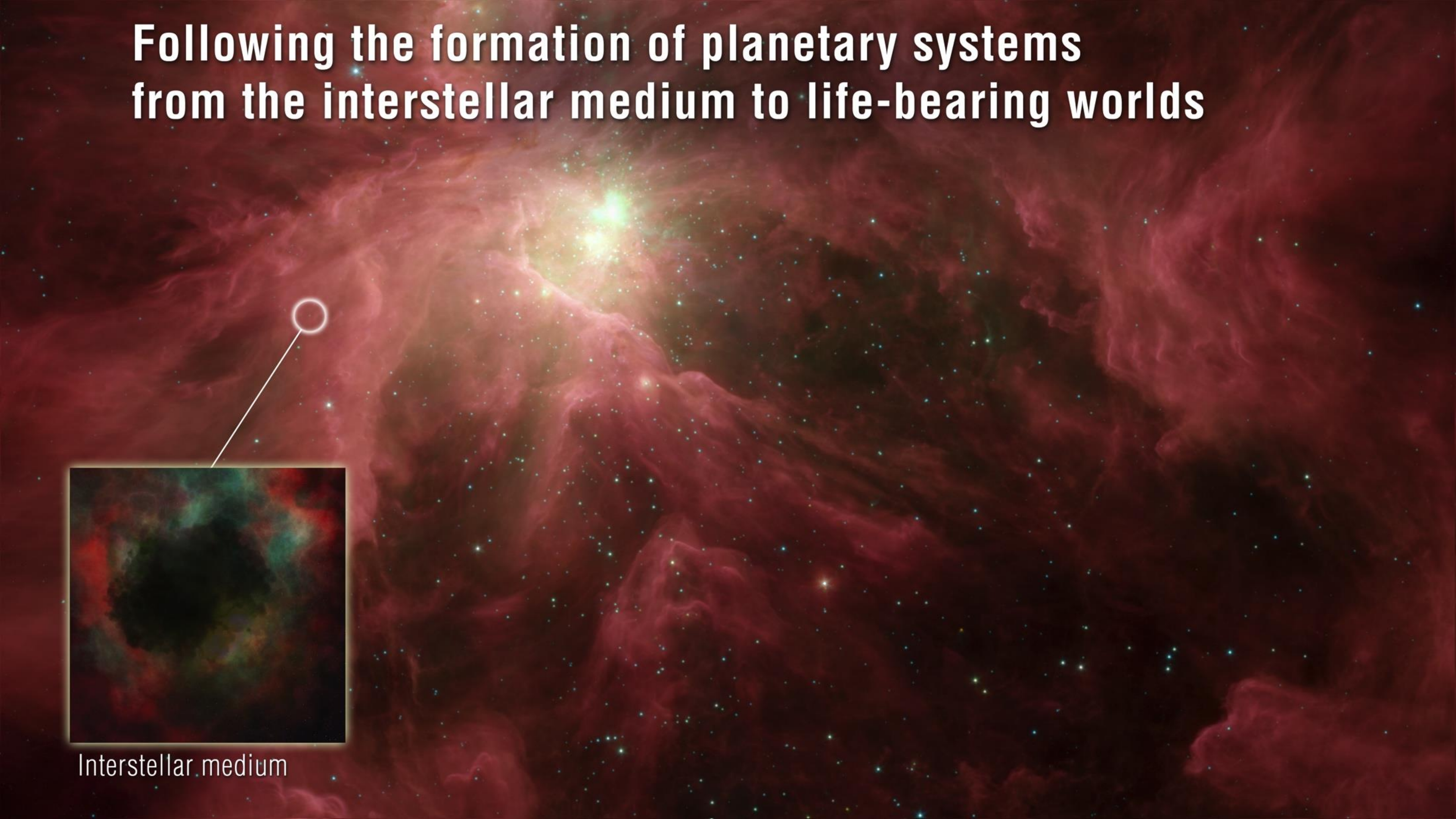
Imaging survey with FIP

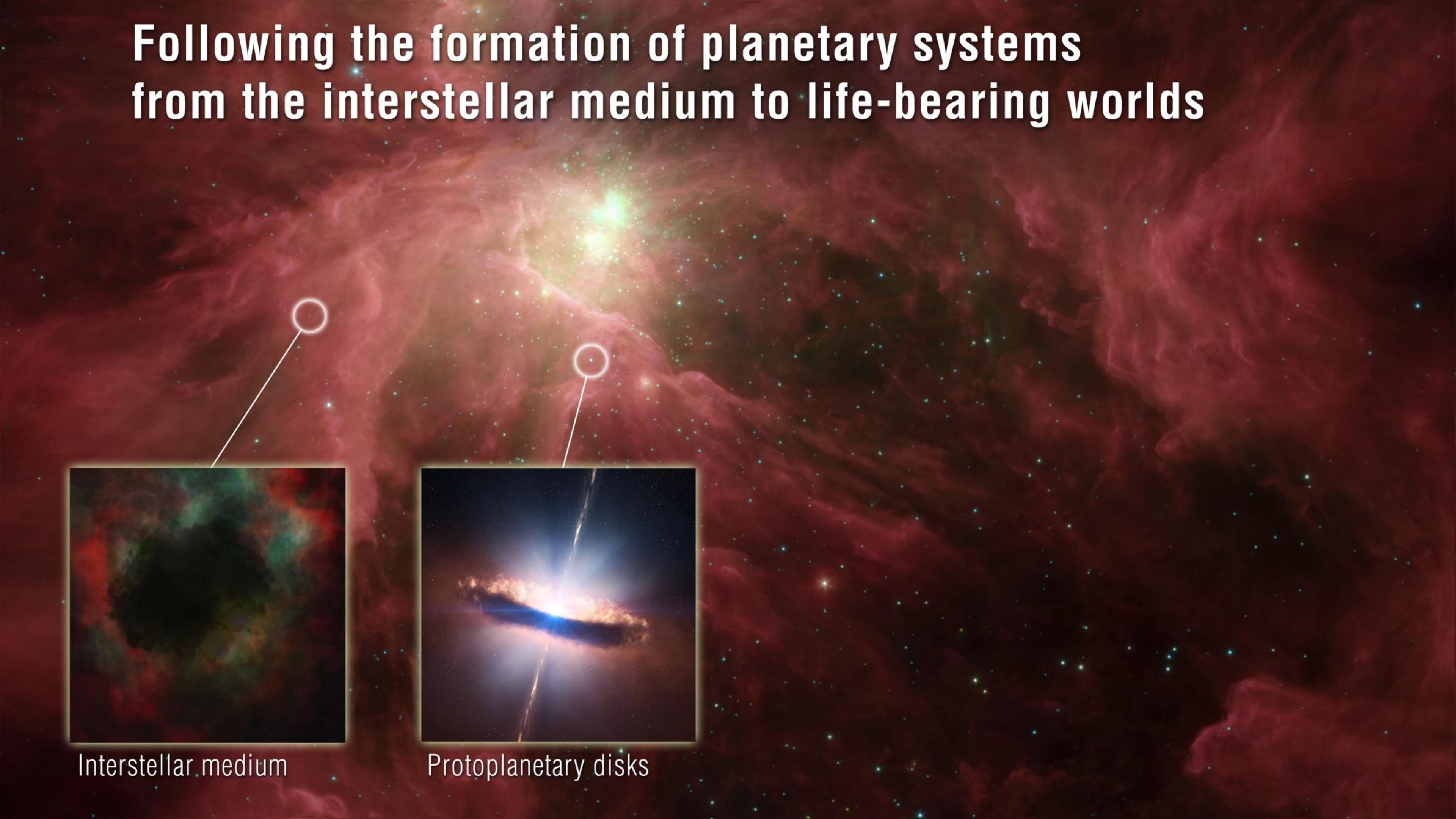
Goal to cover a larger area: ULIRGS @ z=6, millions of galaxies



Magnetic fields (FIP) and turbulence (HERO, HRS)

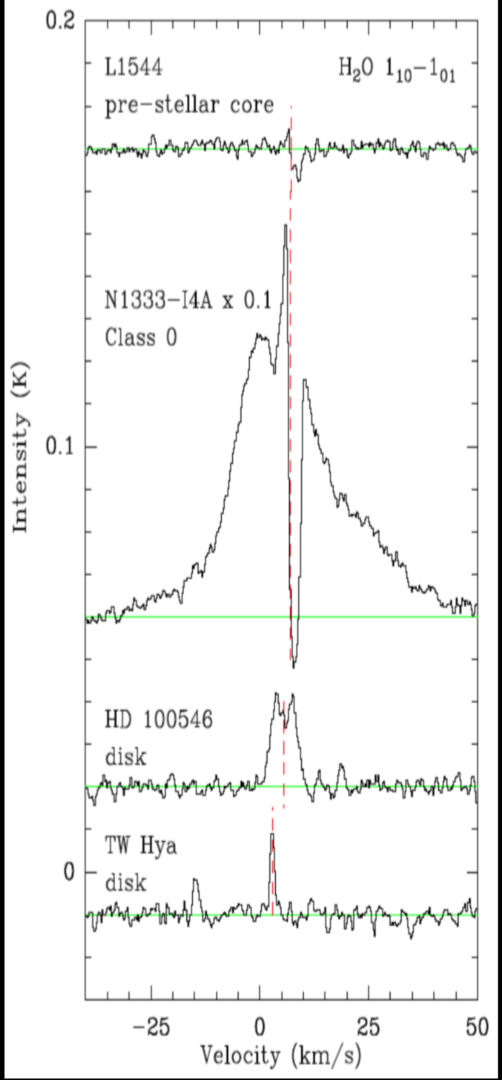


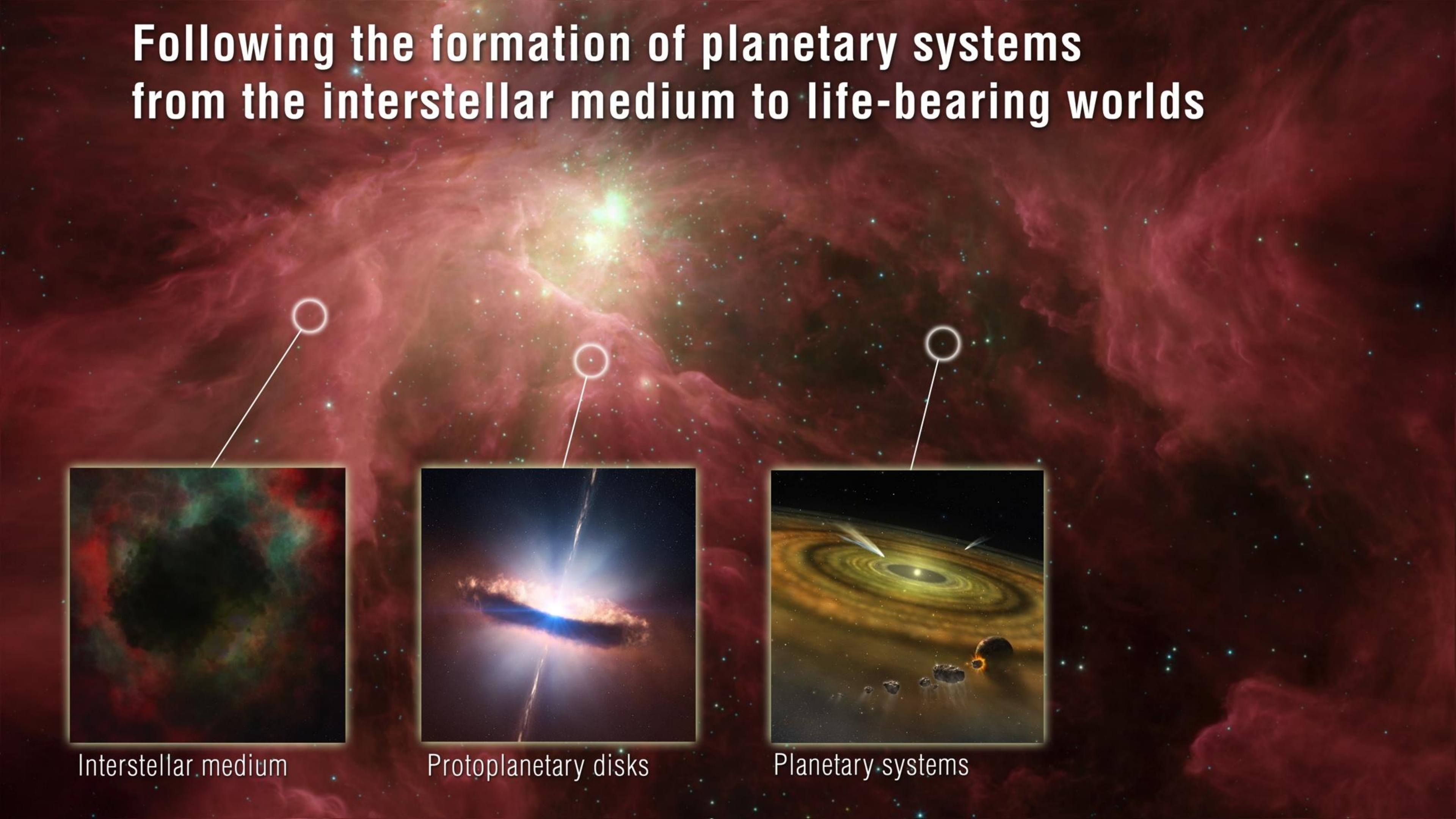

Following the formation of planetary systems
from the interstellar medium to life-bearing worlds
Interstellar medium

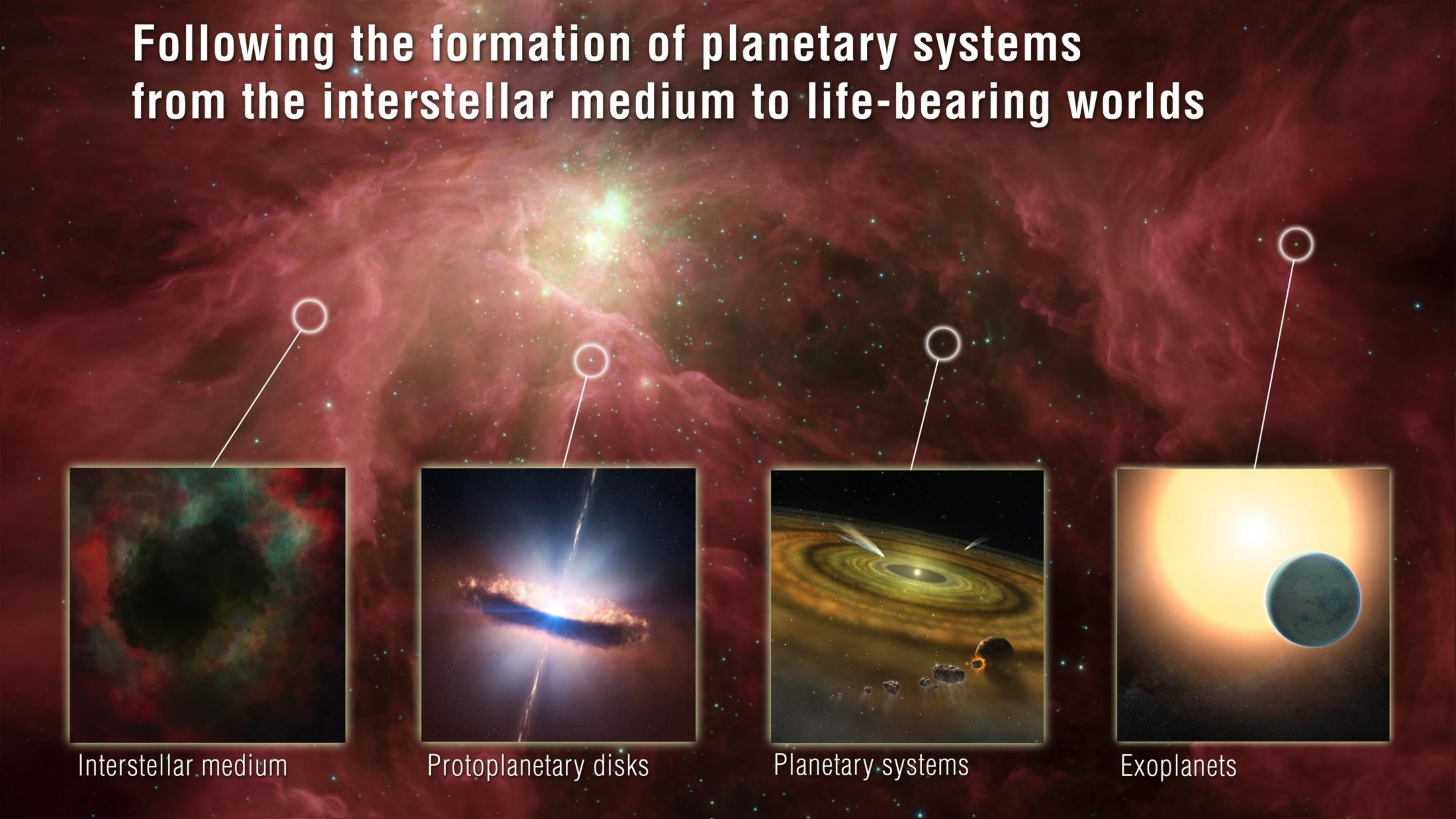

Following the formation of planetary systems
from the interstellar medium to life-bearing worlds
Interstellar medium
Protoplanetary disks

Water Transport to Terrestrial Planetary Zone (HRS, MRSS, HERO)

Science Goal: Observe gas-phase water in interstellar clouds and dense star-forming cores to probe critical processes related to formation and transport of water to the terrestrial planet zone, as a key input to habitability.

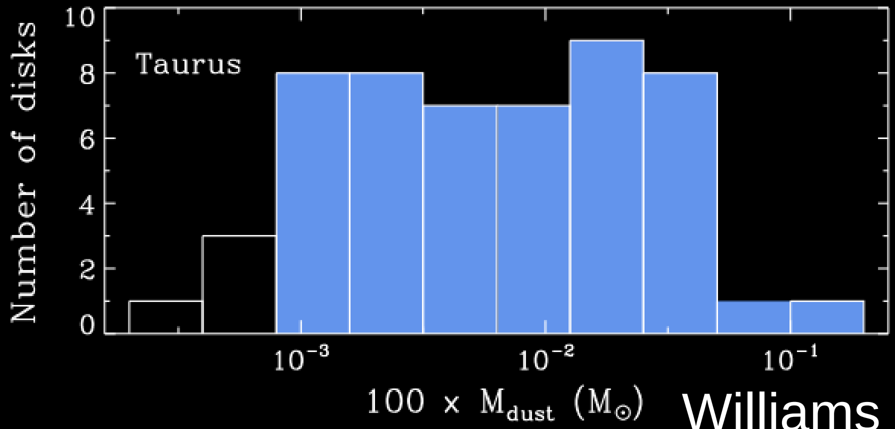



Following the formation of planetary systems
from the interstellar medium to life-bearing worlds
Interstellar medium
Protoplanetary disks
Planetary systems


Following the formation of planetary systems
from the interstellar medium to life-bearing worlds
Interstellar medium
Protoplanetary disks
Planetary systems
Exoplanets

What are ProtoPlanetary disk gas masses? (HRS,MRSS HERO)

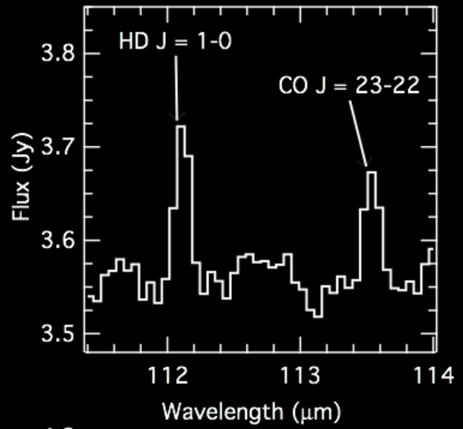
- ➞HD is a million times more emissive than H_2 at T ~ 20 K.
- ➞Atomic D/H ratio inside the local bubble is well characterized (~1.5×10^{-5})
- ➞HD will follow H_2 in the gas

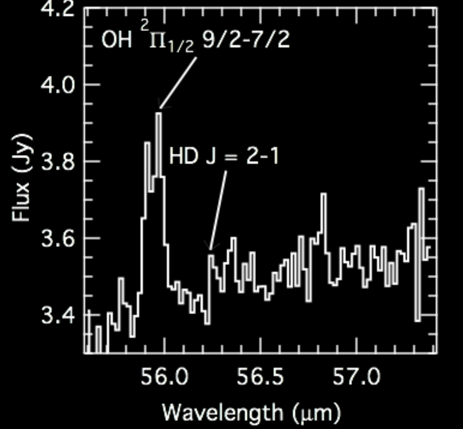


Williams and Cieza 2011

- ➞TW Hya disk mass

$M_{disk} \sim 0.05\ M_\odot$



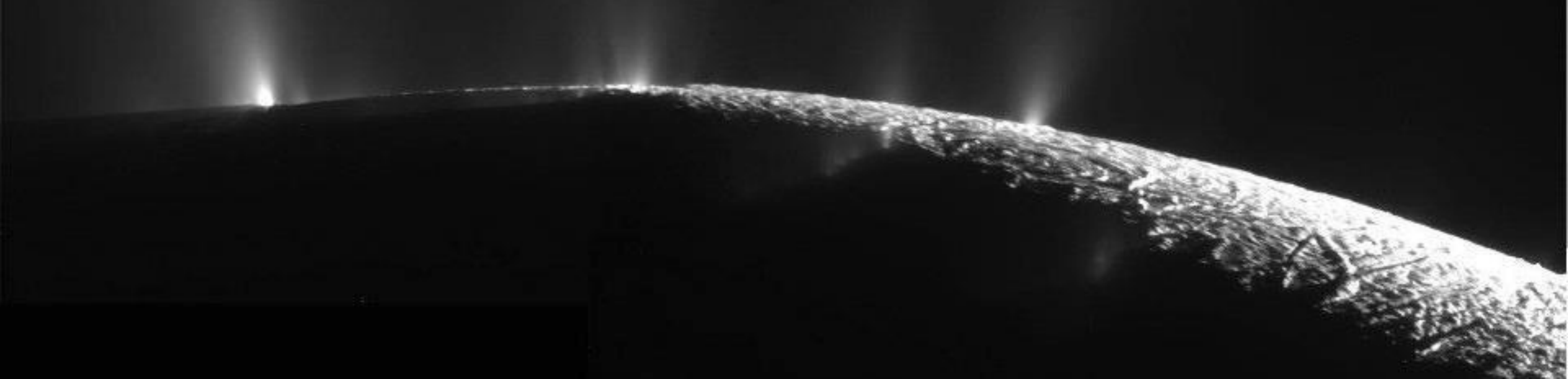


Bergin+ 2013

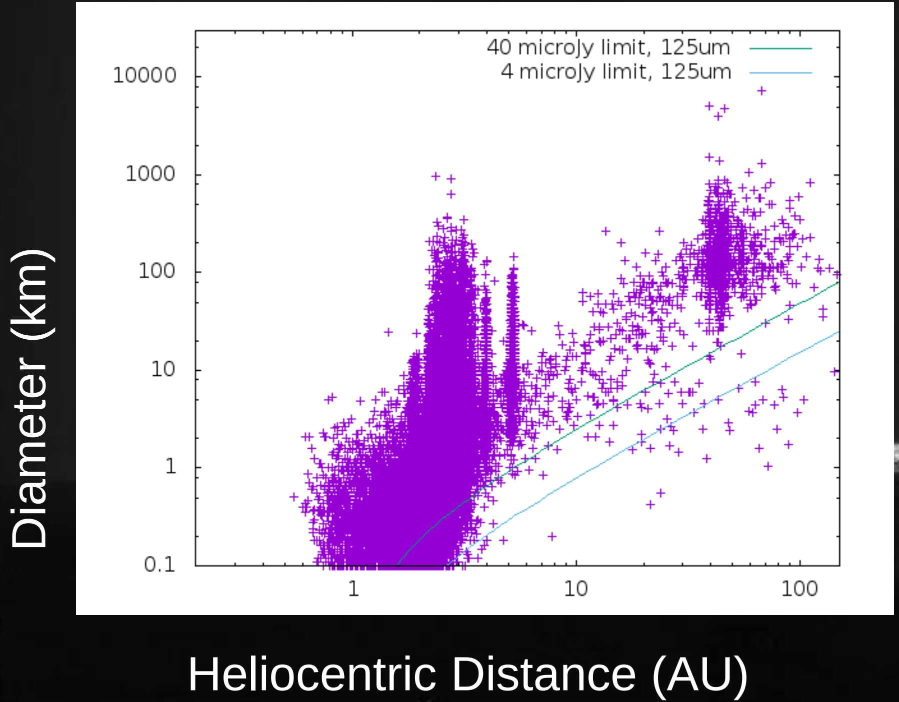
OST places our solar system in context

FIP mapping of Outer Solar System

- Measure the thermal emission (FIP) of small bodies in outer Solar System – 1000's of targets
- **Constrain the thermal history and evolution of the Solar System.**
- Characterize Planet IX?



FIP mapping of Outer Solar System

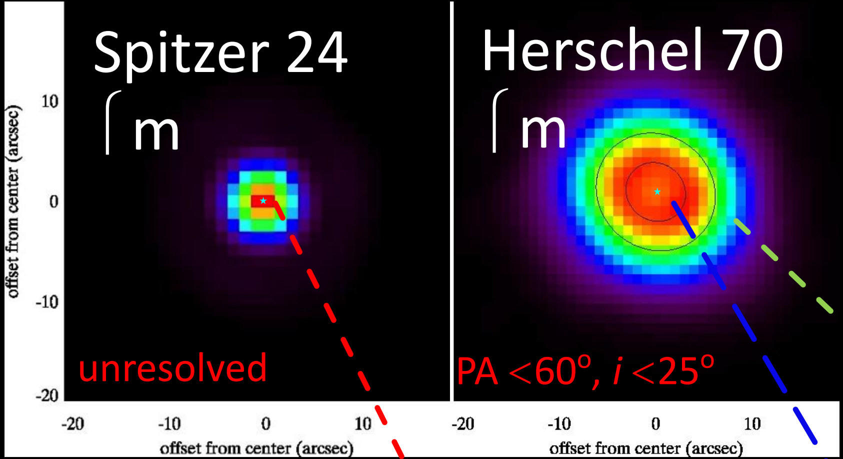


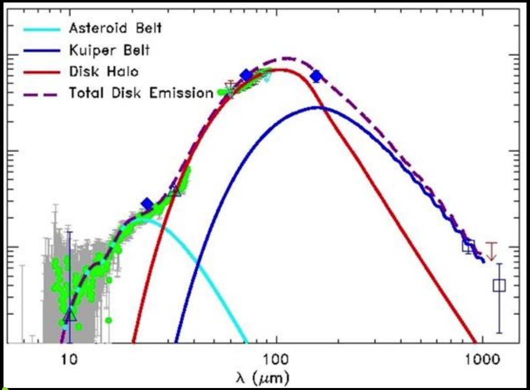
Lovell

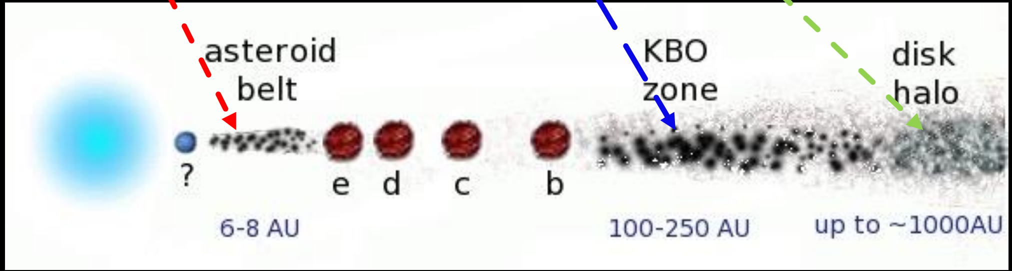
- Measure the thermal emission (FIP) of small bodies in outer Solar System – 1000's of targets
- **Constrain the thermal history and evolution of the Solar System.**
- Characterize Planet IX?

Debris Disks and Giant Planets (FIP)

Spectral Energy Distribuion of HR8799







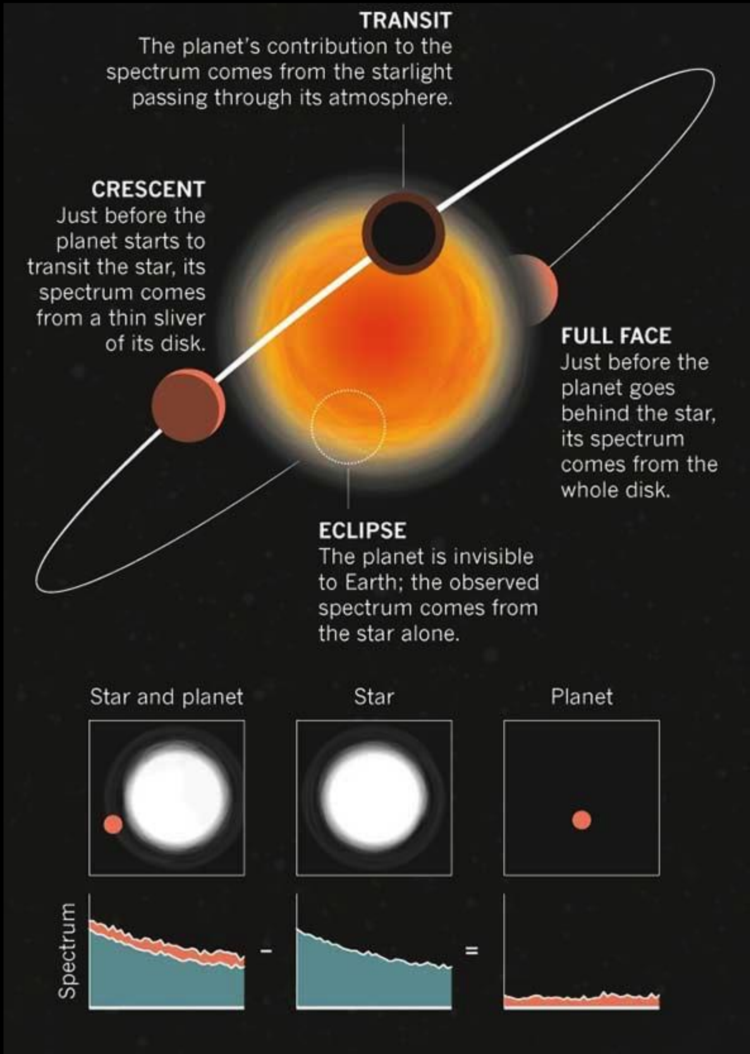
Su et al. 2009
Matthews et al. 2013
Marios et al. 2010

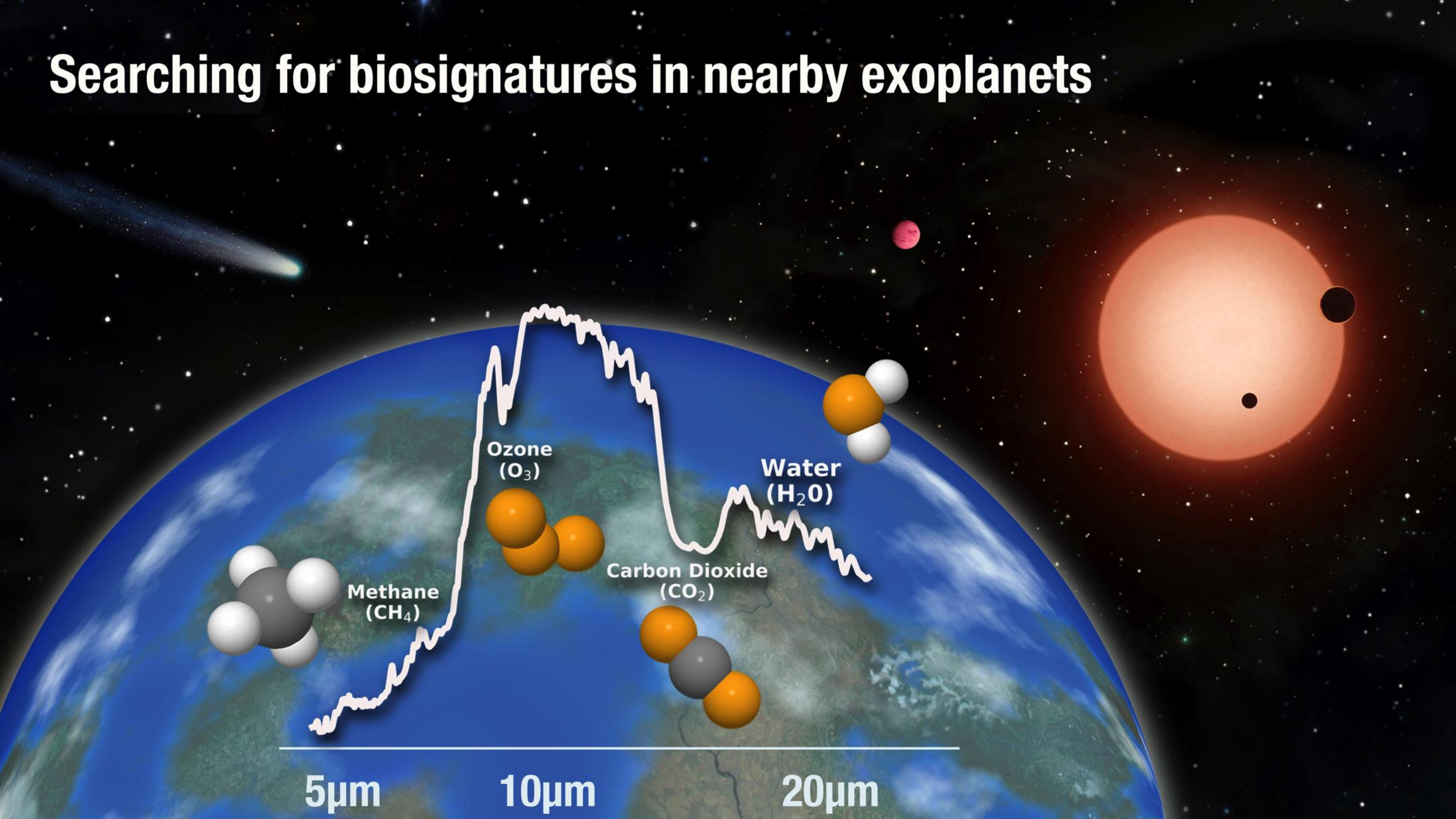
Exoplanets – Transits (MISC)

(See Stevenson: special session Wed.)

Transits for exoplanets

- Primary transit (probes terminator)
- Secondary eclipse (probes dayside)
- Lightcurves can indicate further patterns (time consuming)
- Atmosphere Characterization
- Biosignatures



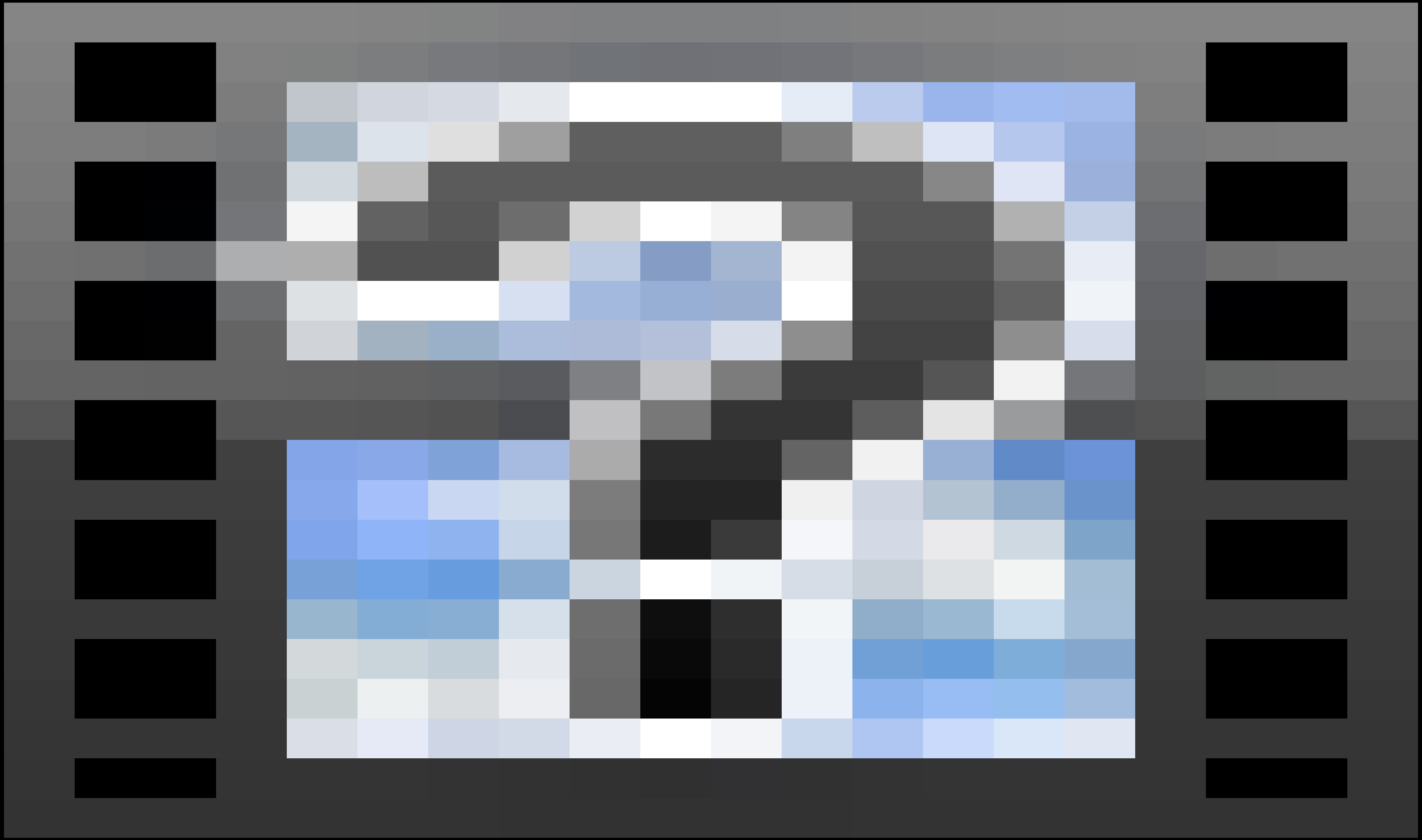

Searching for biosignatures in nearby exoplanets
Ozone
(O_3)
Water
(H_2O)
Carbon Dioxide
(CO_2)
Methane
(CH_4)
5µm
10µm
20µm

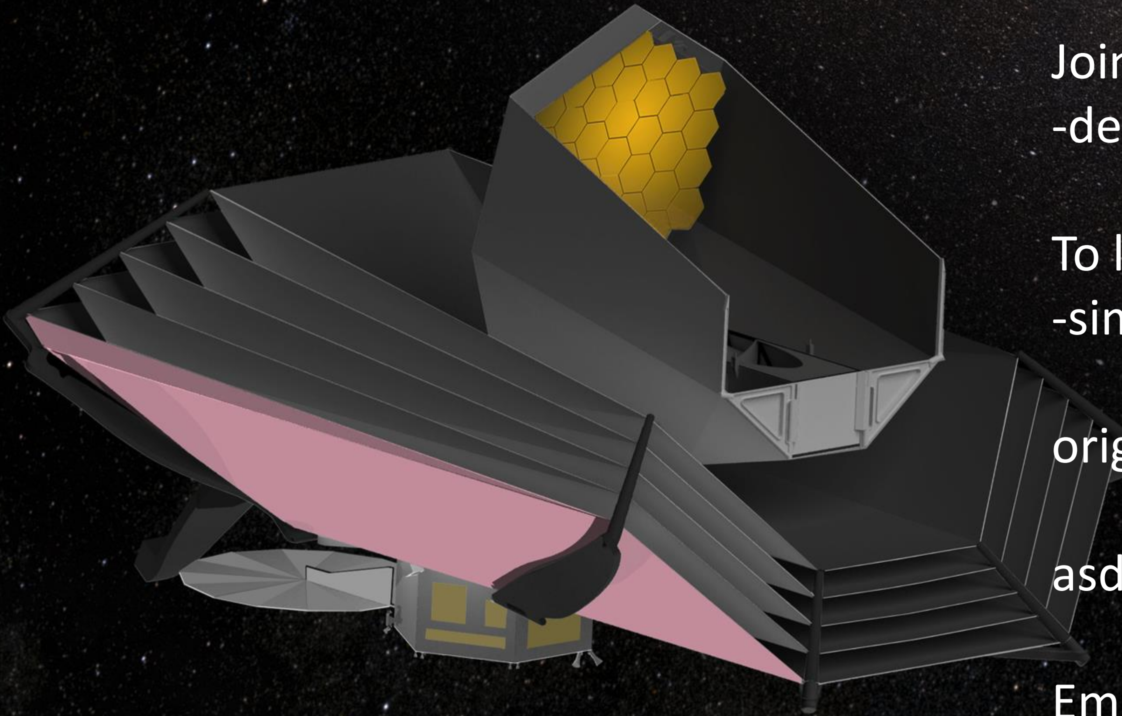
Exoplanets – Coronagraph (MISC)

Main targets: Warm Gas Giants & Jupiters
Interesting to help our view of whole Planetary systems

- because of the large IWA, no HZ planets
- Direct imaging doe not drive HZ planet case

Ground-based ELTs searches can provide complimentary VIS/NIR data for such planets





Join us!
-define the science for OST

To learn more:
-simulation tools for OST

origins.ipac.caltech.edu

asd.gsfc.nasa.gov/firs/

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Secret word: OST@COPAG