Let’s discover our ORIGINS

ORIGINS
Space Telescope

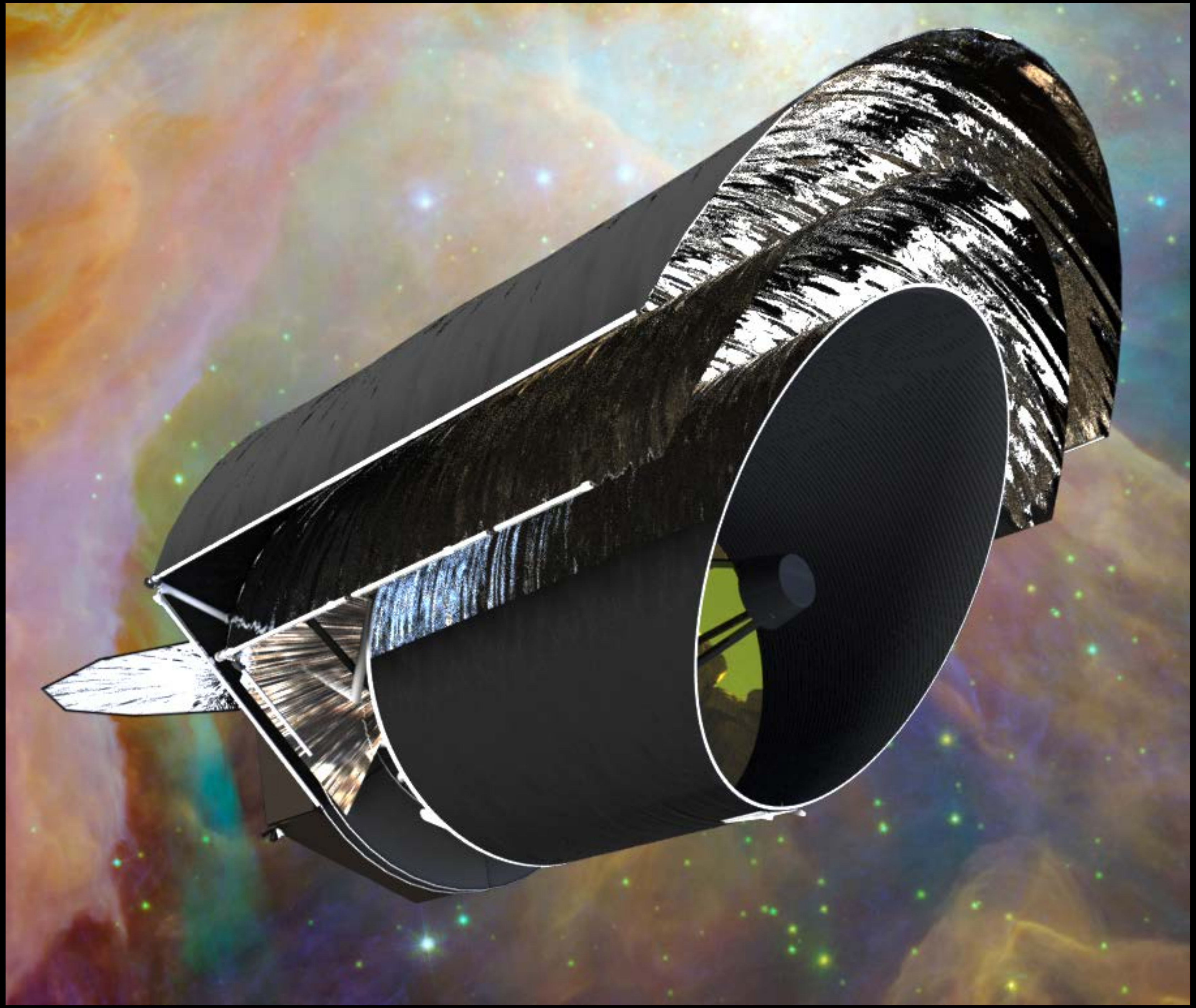
How does the universe work?

How did we get here?

Are we alone?

Discovery of new phenomena

- ★ x1000 more sensitive than anything before
- ★ 5.9m aperture non-deployed cold aperture (4.5K)
- ★ Low-risk development, testing, and deployment
- ★ Mid and Far - IR has rich chemical and physical information



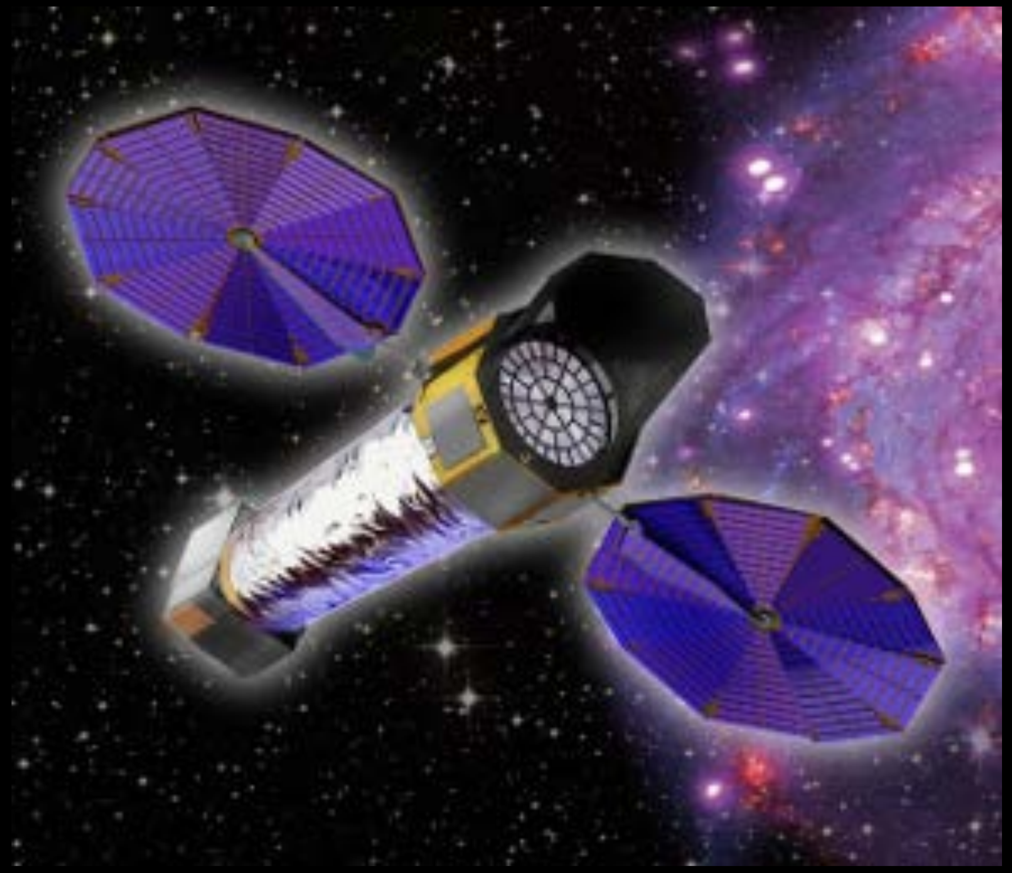
ORIGINS Space Telescope

Margaret Meixner (STScI/JHU)
Community Co-Chair,
Origins Science and Technology Definition Team

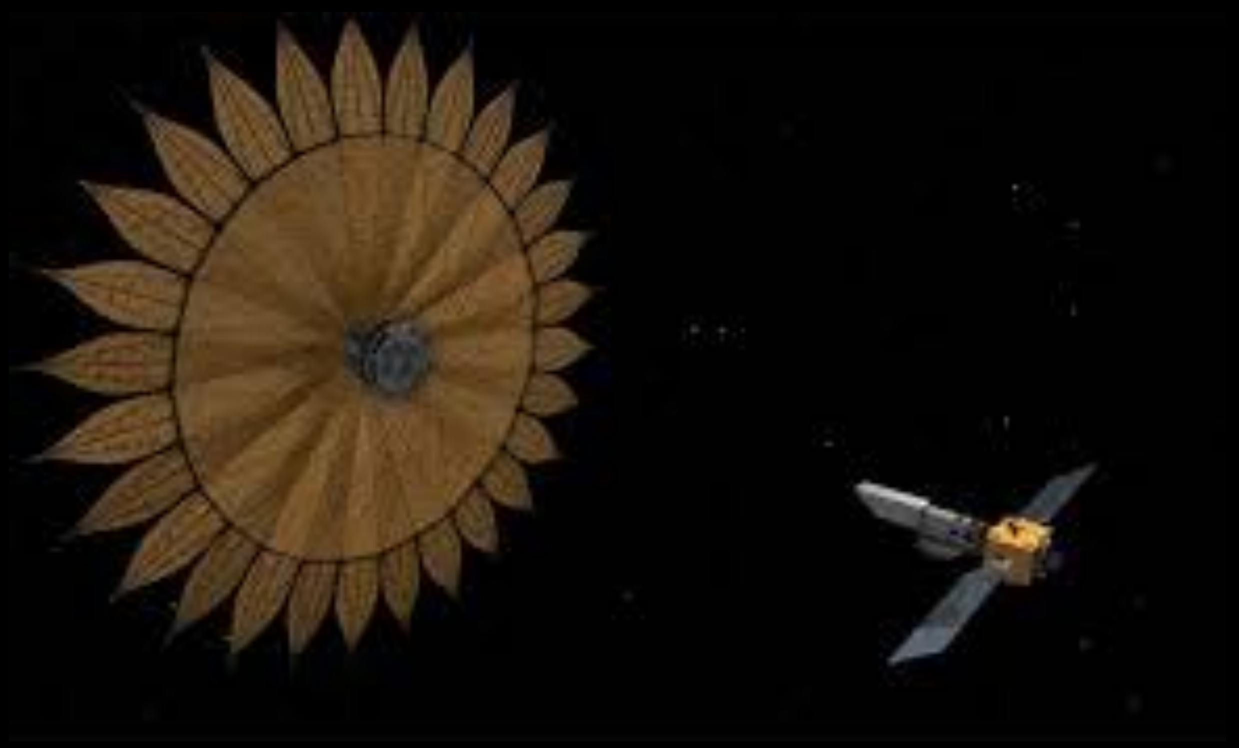
http://origins.ipac.caltech.edu @OriginsTele

Large Mission Studies for Decadal

Origins Space Telescope
Margaret Meixner (STScI/JHU)
Asantha Cooray (UC Irvine)



Lynx
Feryal Ozel (U. Arizona)
Alexey Vikhilin (Harvard/CfA)



Habex
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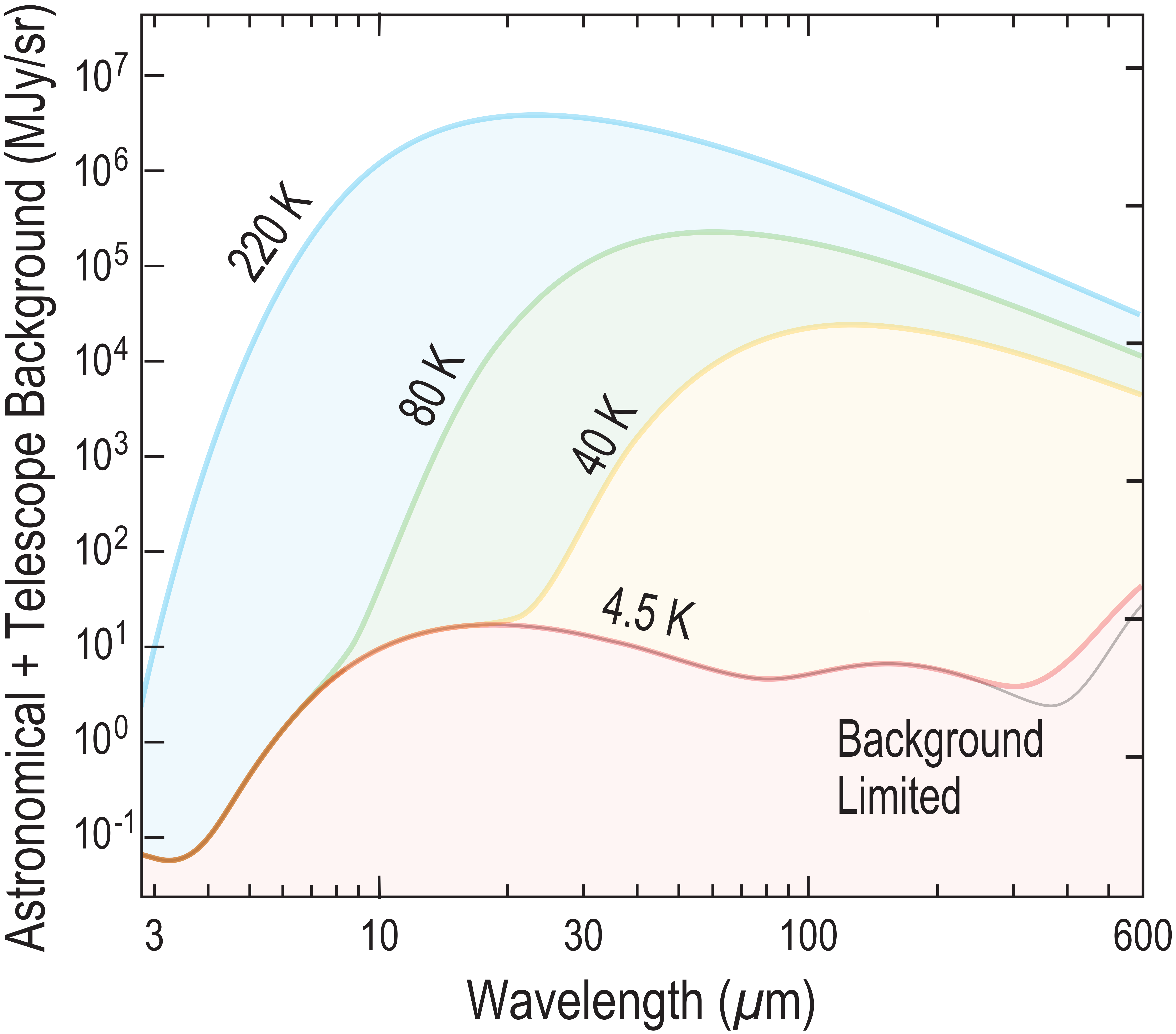
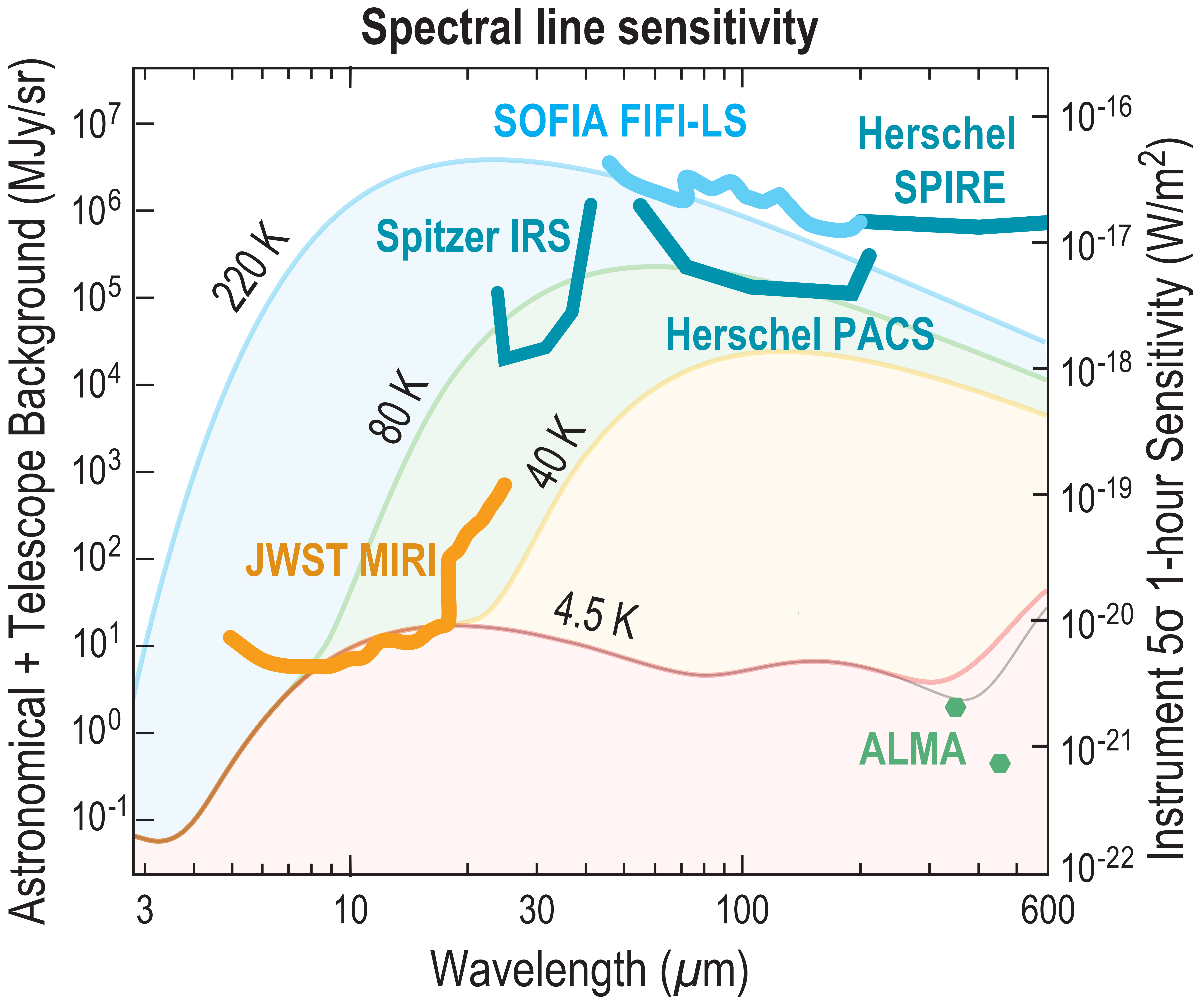
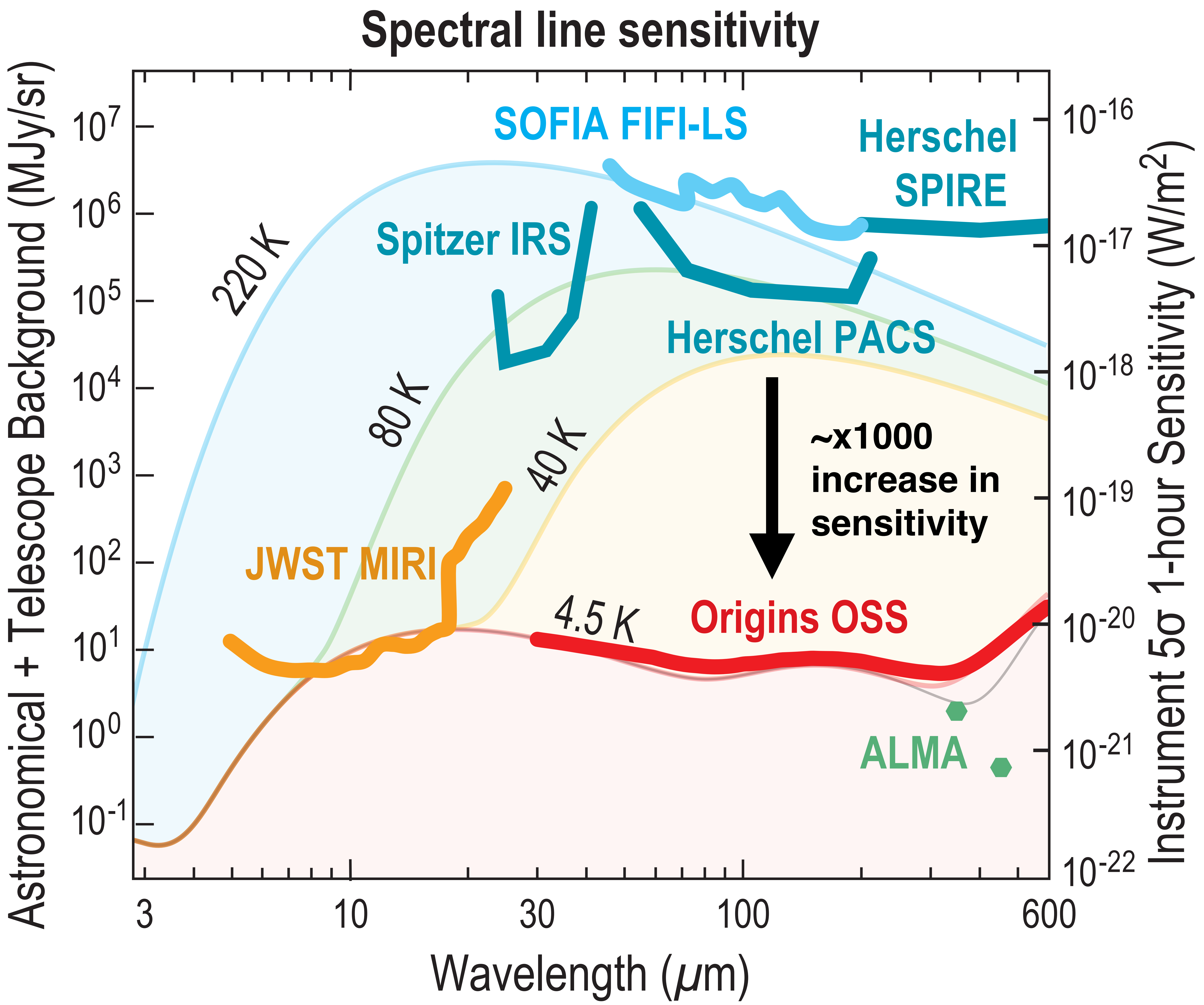
Scott Gaudi (OSU)

LUVOIR
Debra Fischer (Yale)
Brad Peterson (OSU)


Astronomical + Telescope Background (MJy/sr)
10^7
10^6
10^5
10^4
10^3
10^2
10^1
10^0
10^-1
220 K
80 K
40 K
4.5 K
Background
Limited
3
10
30
100
600
Wavelength (μm)



Spectral line sensitivity
Astronomical + Telescope Background (MJy/sr)
Instrument 5σ 1-hour Sensitivity (W/m2)
Wavelength (μm)
SOFIA FIFI-LS
Herschel SPIRE
Spitzer IRS
Herschel PACS
JWST MIRI
ALMA
220 K
80 K
40 K
4.5 K
10^7
10^6
10^5
10^4
10^3
10^2
10^1
10^0
10^-1
10^-16
10^-17
10^-18
10^-19
10^-20
10^-21
10^-22
3
10
30
100
600



Spectral line sensitivity
Astronomical + Telescope Background (MJy/sr)
Instrument 5σ 1-hour Sensitivity (W/m2)
Wavelength (μm)
3
10
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10^7
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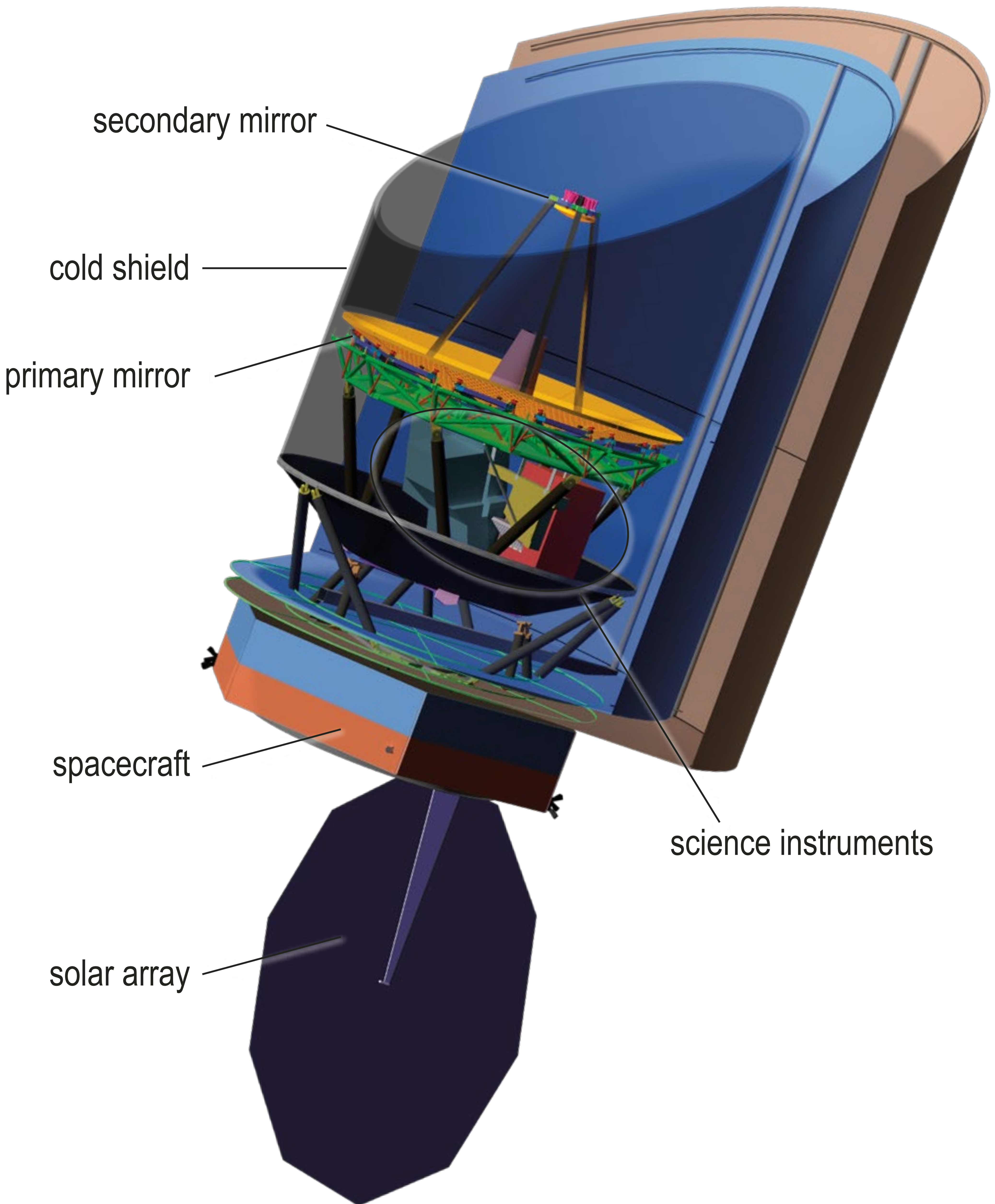
10^3
10^2
10^1
10^0
10^-1
10^-16
10^-17
10^-18
10^-19
10^-20
10^-21
10^-22
SOFIA FIFI-LS
Herschel SPIRE
Spitzer IRS
Herschel PACS
220 K
80 K
40 K
4.5 K
JWST MIRI
Origins OSS
ALMA
~x1000 increase in sensitivity

Origins: Spitzer-like minimal deployable design



wavelength coverage: 2.8-588 μm

Telescope:

- diameter: 5.9 m
- area: 25 m^2 (=JWST area)
- diffraction-limit: 30 μm
- temperature: 4.5 K

Cooling: long life gyro-coolers

Observatory Mapping Speed: 60” per second

Launch Vehicle:

Large, SLS Block 1, Space-X Starship

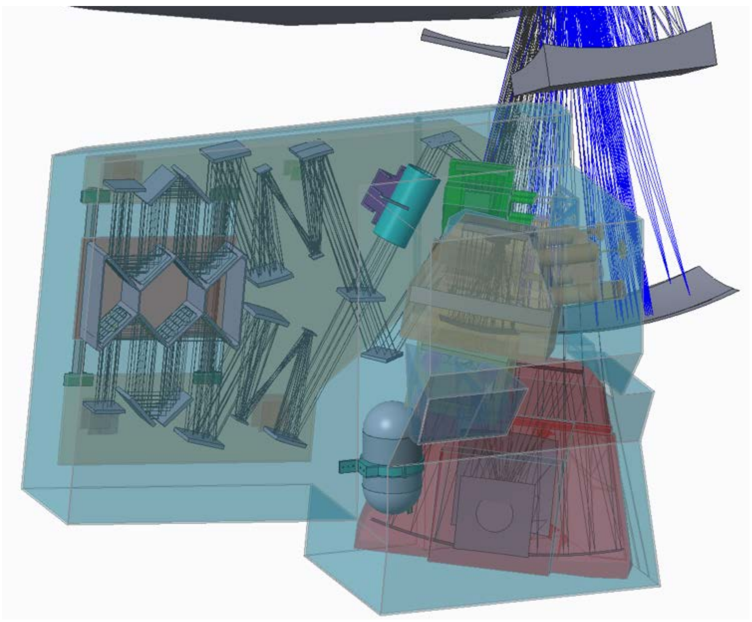
Lifetime: 5 years, 10 year propellant

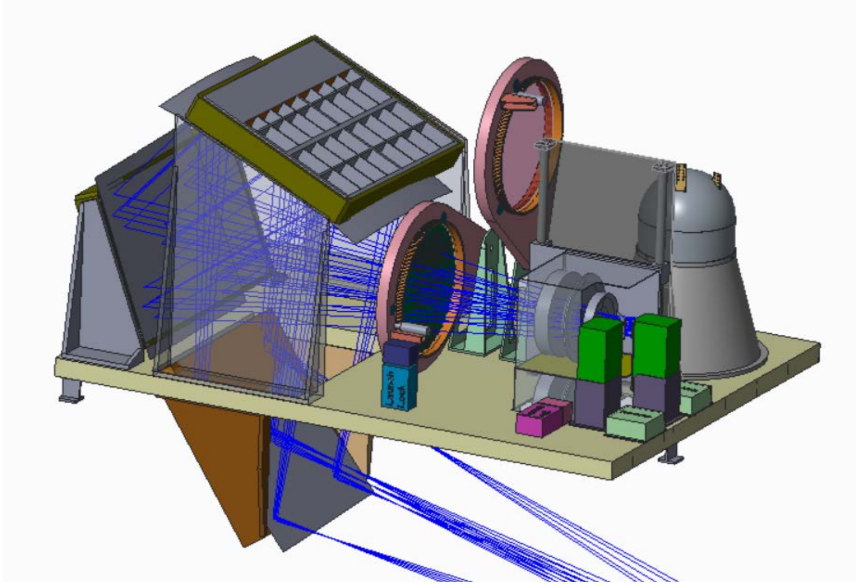
Orbit: Sun-Earth L2

Three Instruments

OSS: Origins Survey Spectrometer

-25-588 μm R~300, survey mapping
-25-588 μm R~43,000
-100-200 μm R~325,000



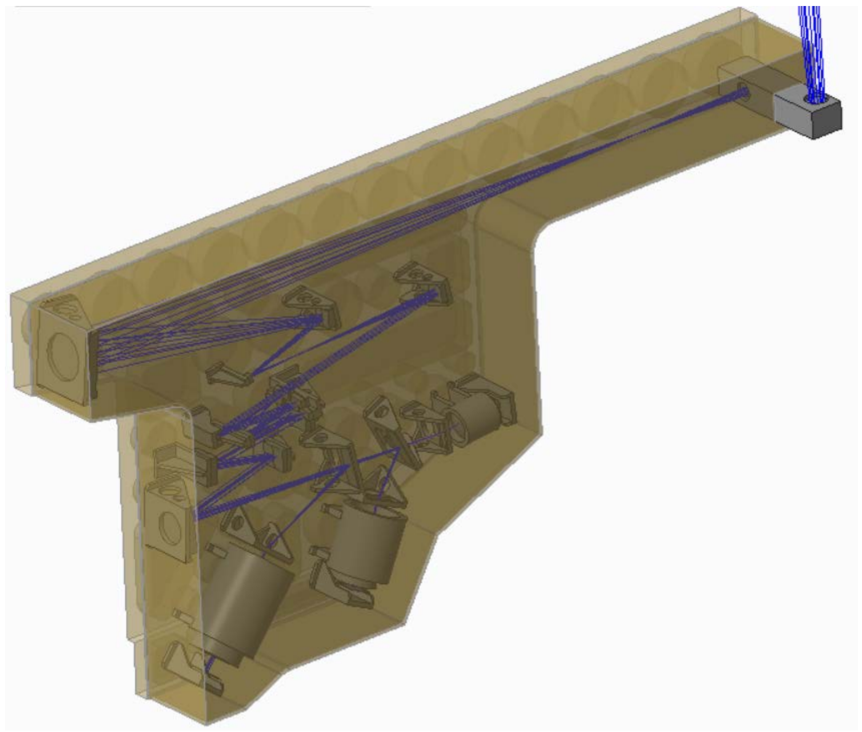


FIP: Far-infrared Imager Polarimeter

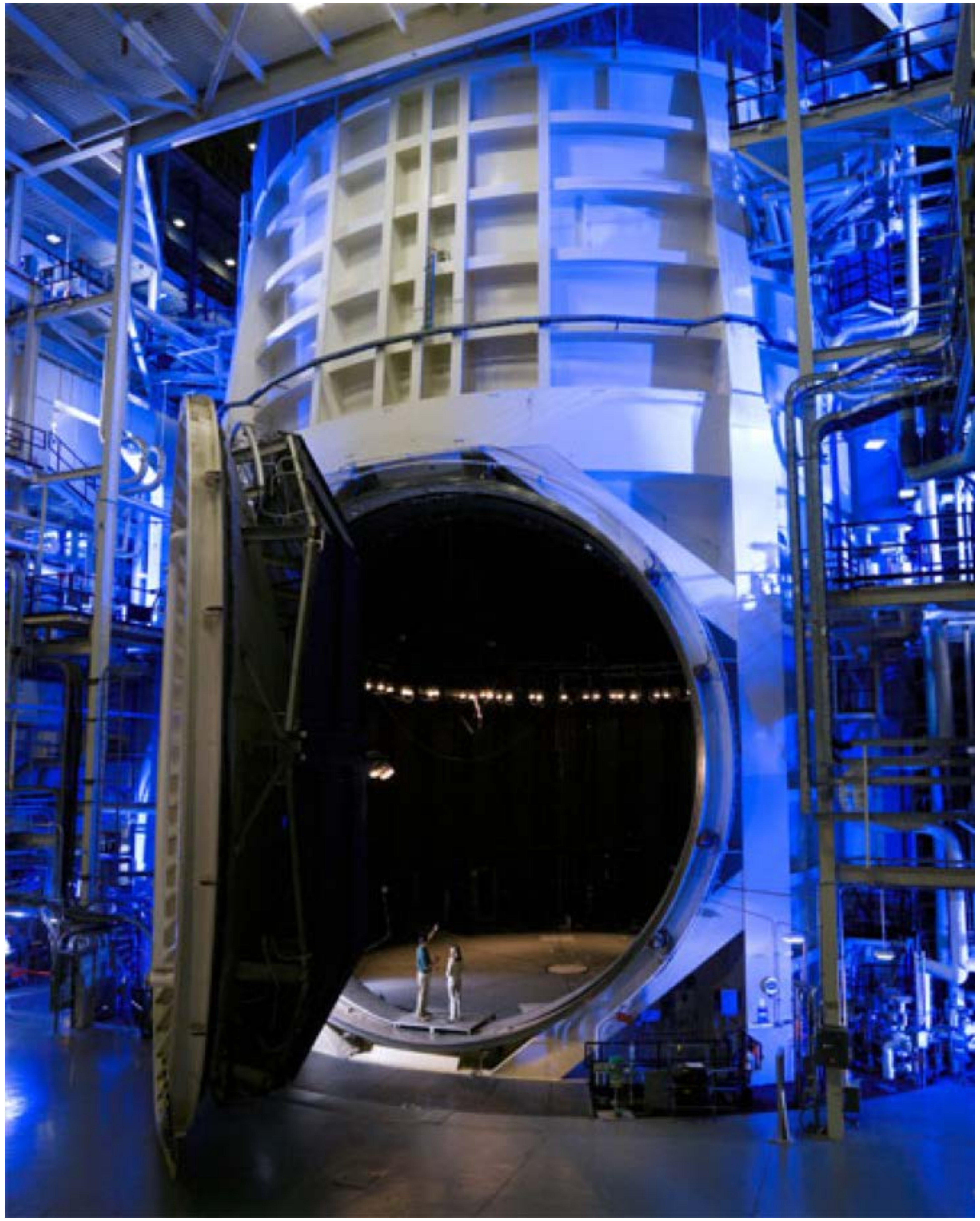
- 50 or 250 μm, Large area survey mapping
- 50 or 250 μm, polarimetry

MISC-T: Mid-Infrared Spectrometer Camera Transit

-Ultra-Stable Transit Spectroscopy
-2.8-20 μm R~50-295



ORIGINS
Space Telescope



Observatory Integration and test re-uses Johnson Space flight Center Chamber A: end-to-end, “test as you fly”

Technologies

Detectors: tall pole and we have a plan

Far-IR: improved sensitivity

increase pixel count (~10^4)

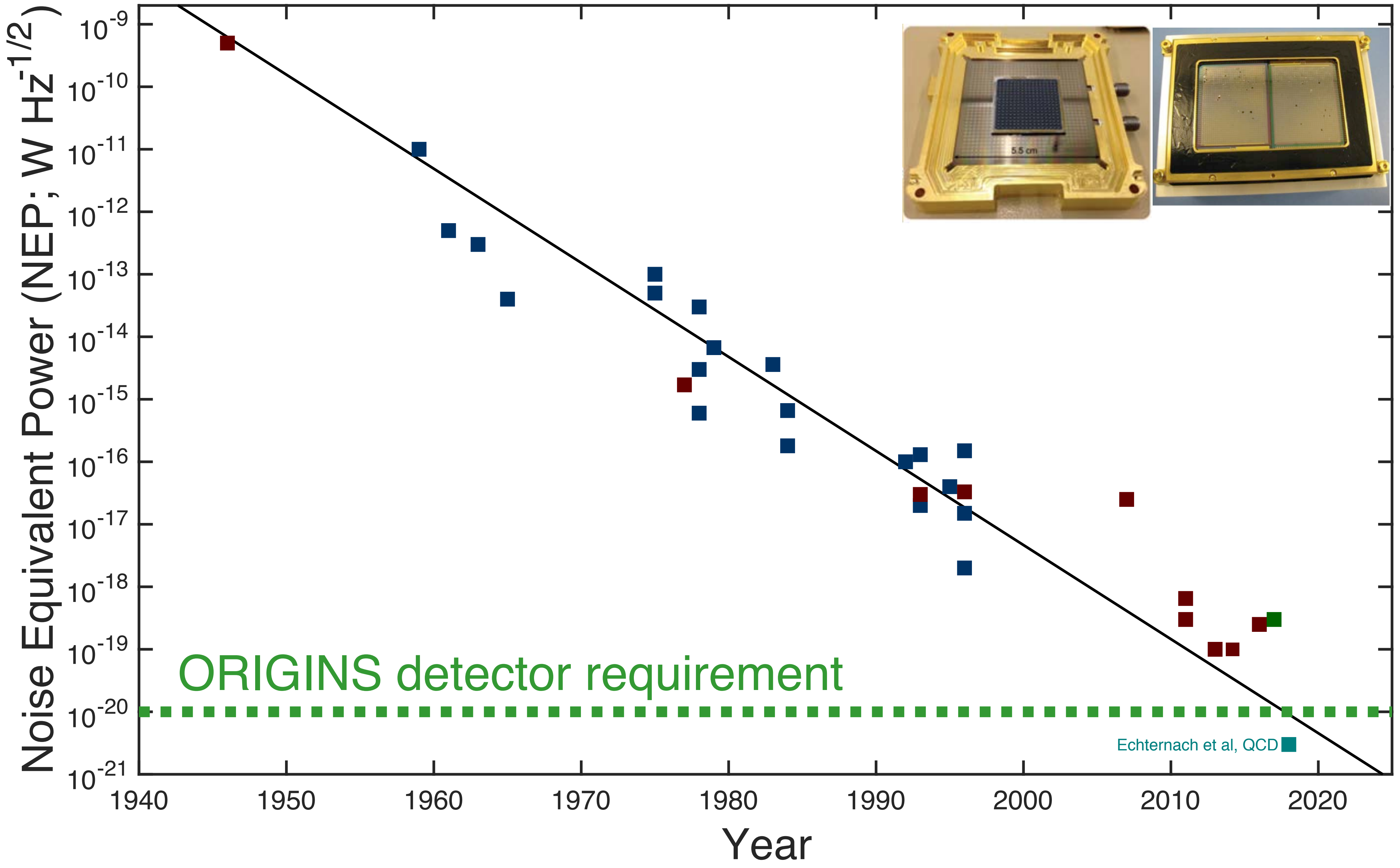
KIDs, TES

Mid-IR: improved relative spectral stability, 5 ppm

state of art: 20-50 ppm

HgCdTe, Si:As, TES

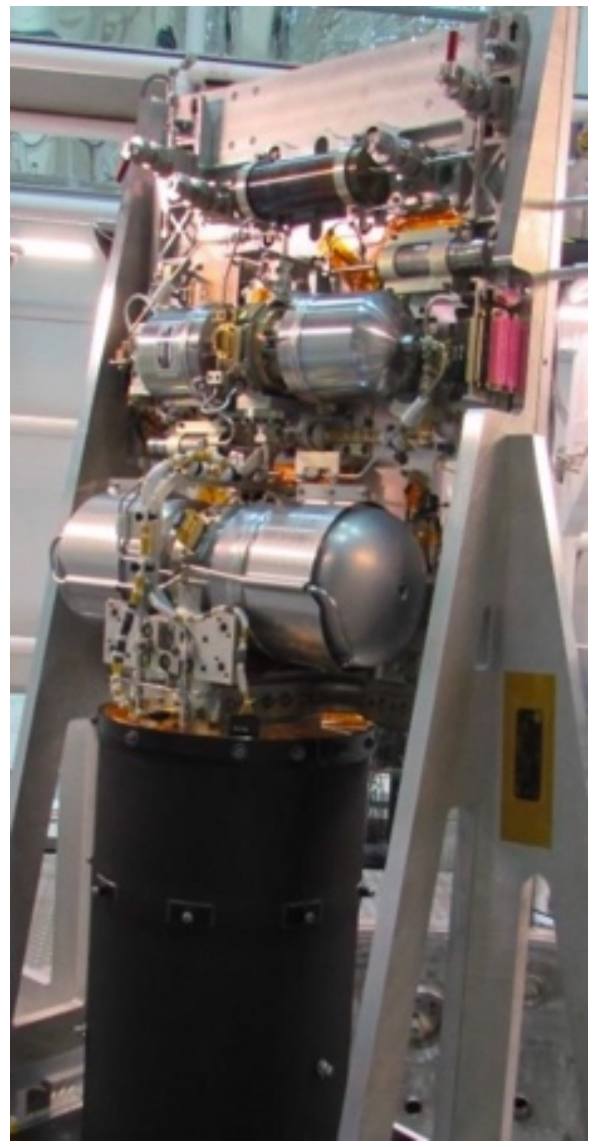
Far-IR: KIDs or TES



Cryocoolers: almost there

-4.5 K: Thanks JWST + Hitomi!

-50 mK: NASA Dev.

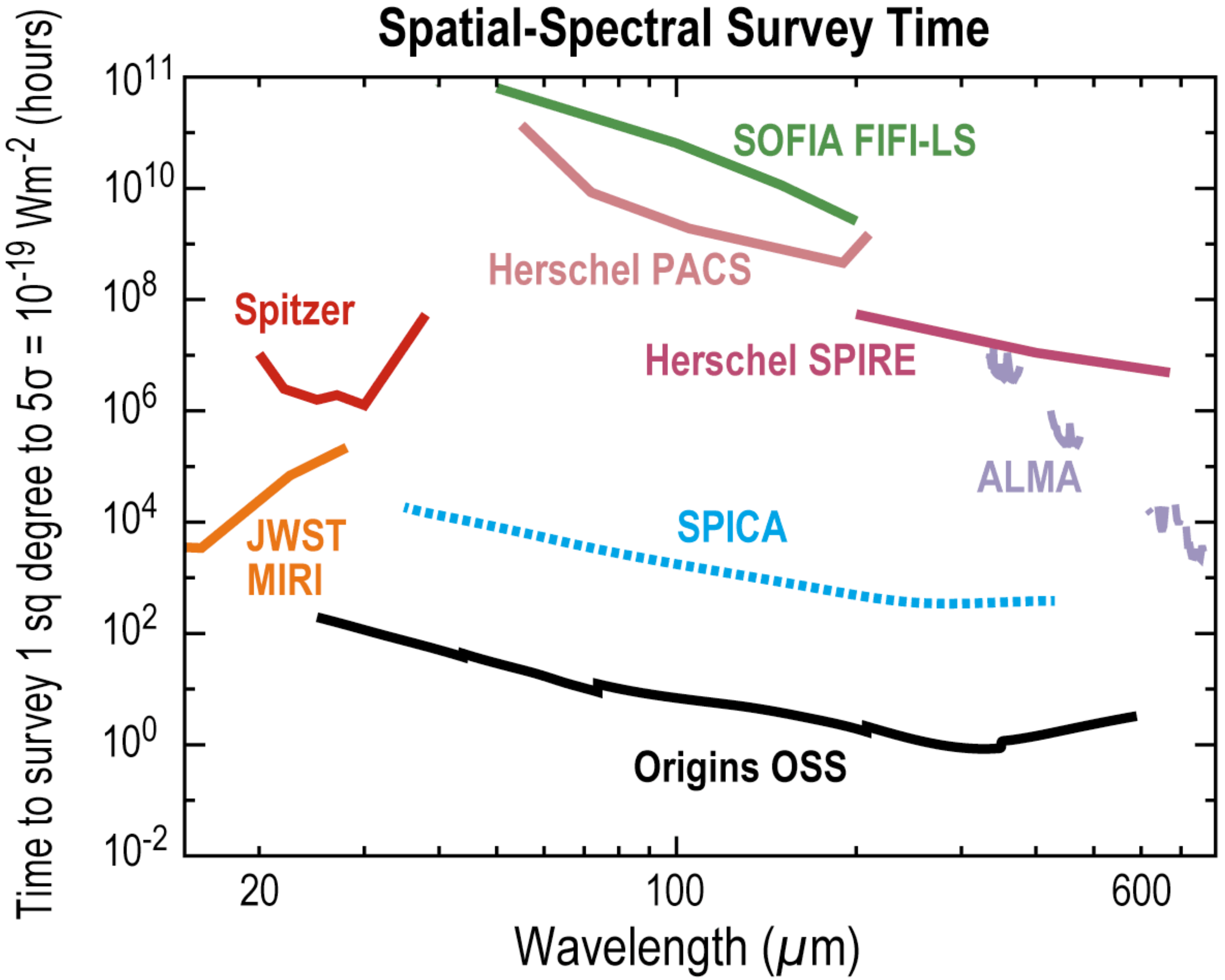


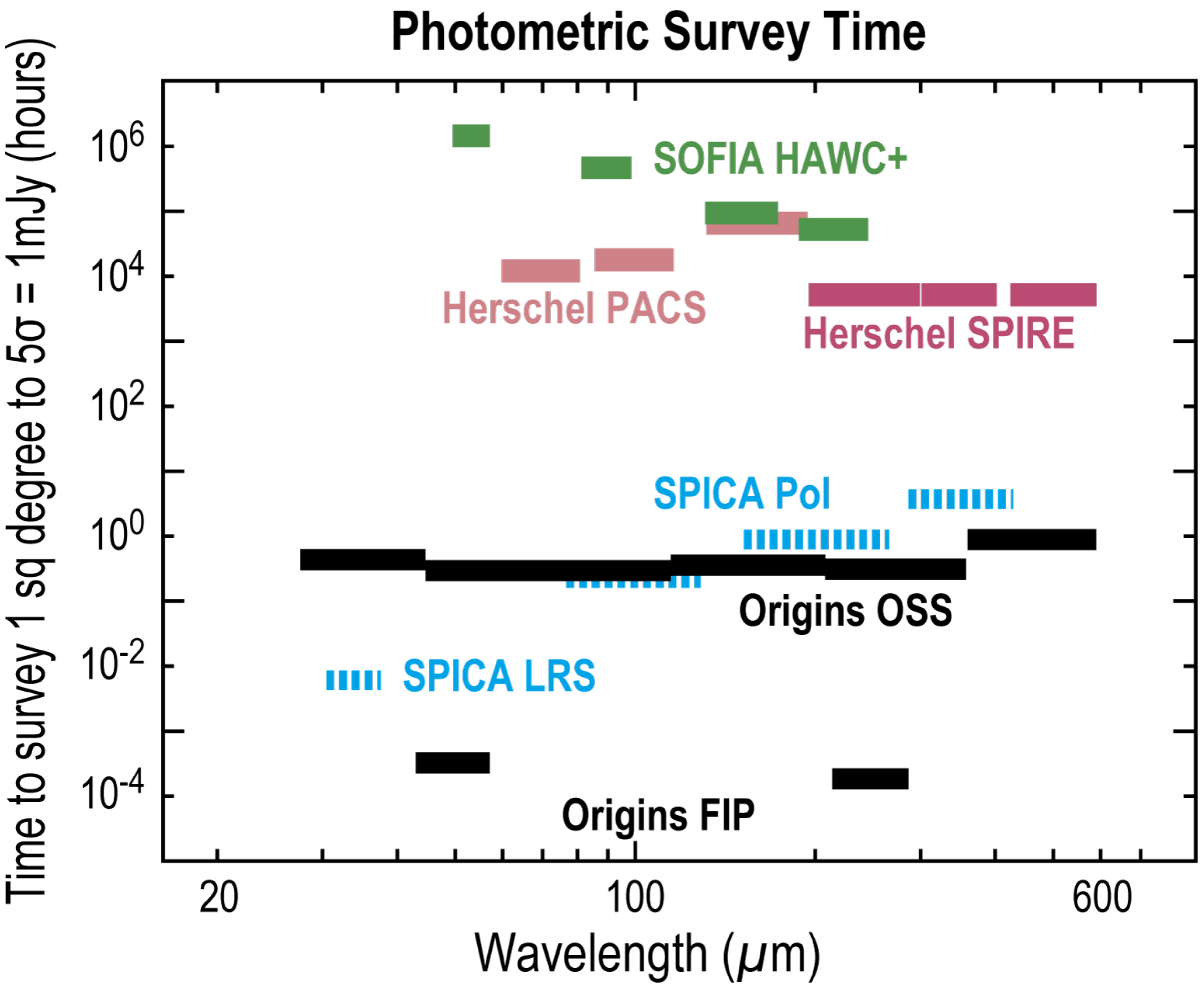
NGAS JWST/

SHI Hitomi/

ORIGINS Space Telescope

Origins Mission Development Timeline


Spatial-Spectral Survey Time
Time to survey 1 sq degree to 5σ = 10-19 Wm-2 (hours)
Wavelength (μm)
SOFIA FIFI-LS
Herschel PACS
Spitzer
Herschel SPIRE
ALMA
SPICA
JWST MIRI
Origins OSS


Photometric Survey Time
Time to survey 1 sq degree to 5σ = 1mJy (hours)
Wavelength (μm)
SOFIA HAWC+
Herschel PACS
Herschel SPIRE
SPICA Pol
Origins OSS
SPICA LRS
Origins FIP

ORIGINS
Space Telescope

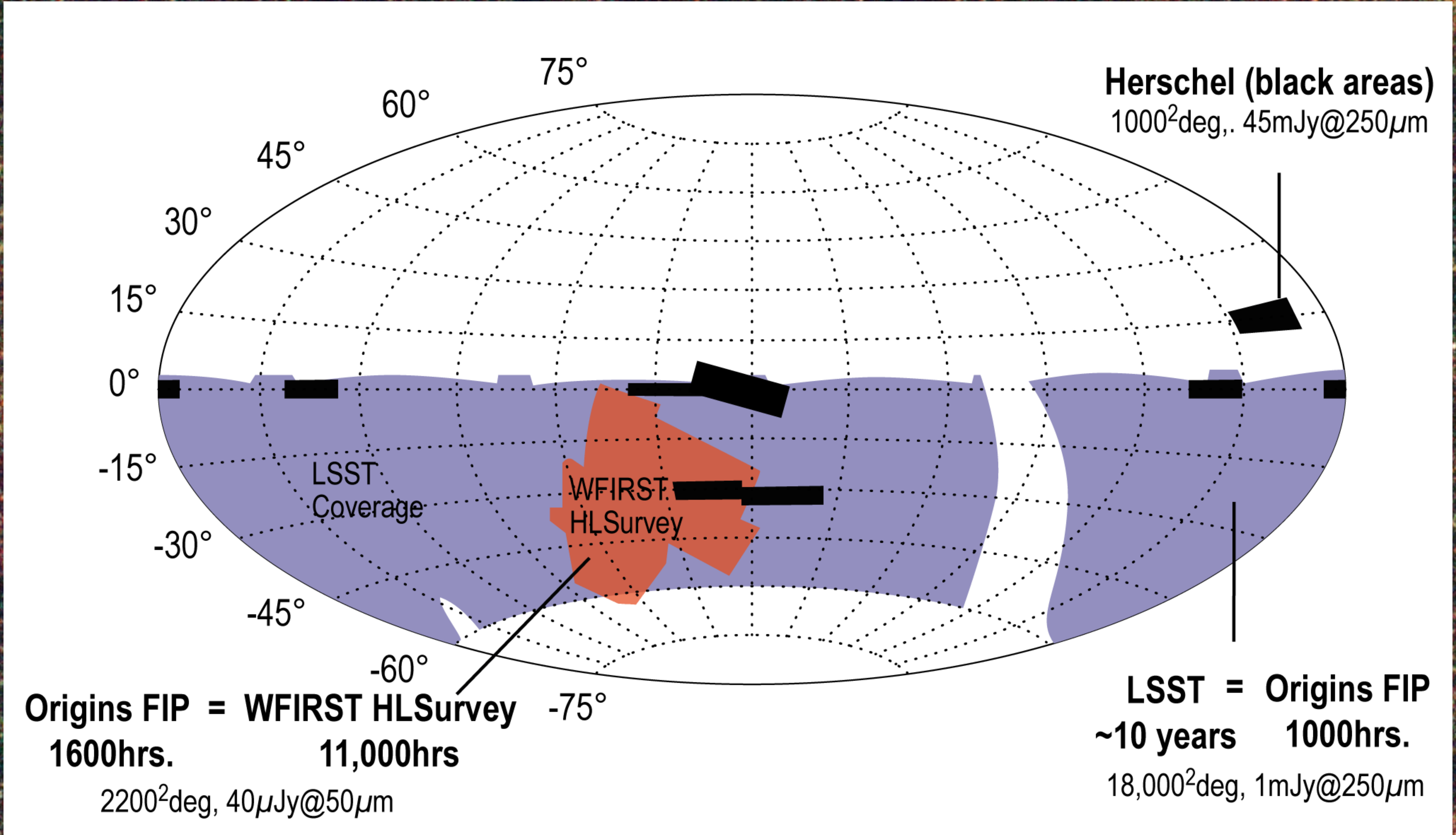
How does the universe work?

How did we get here?

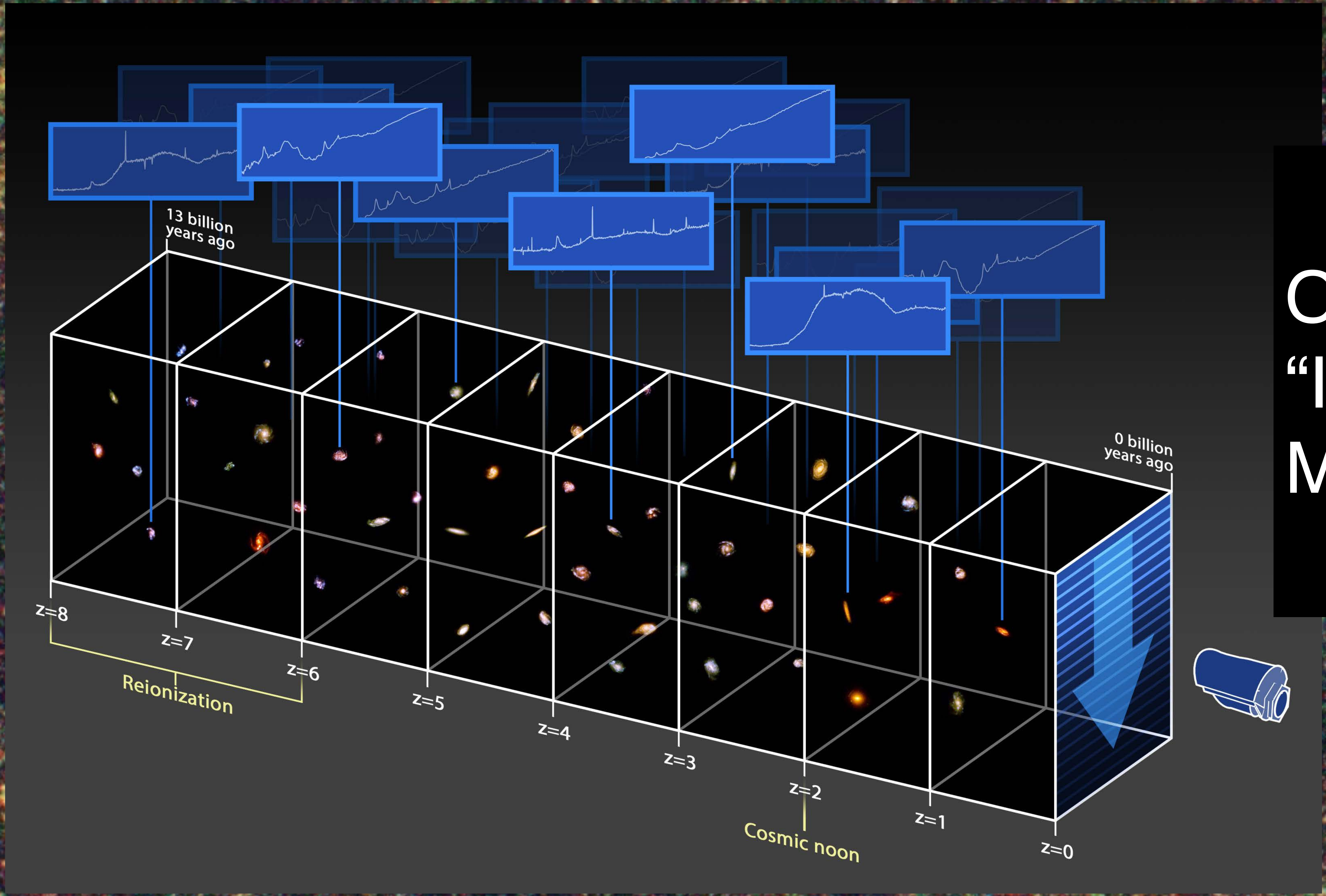
Are we alone?

Discovery of new phenomena

Origins/FIP Surveys: Billion Galaxies!



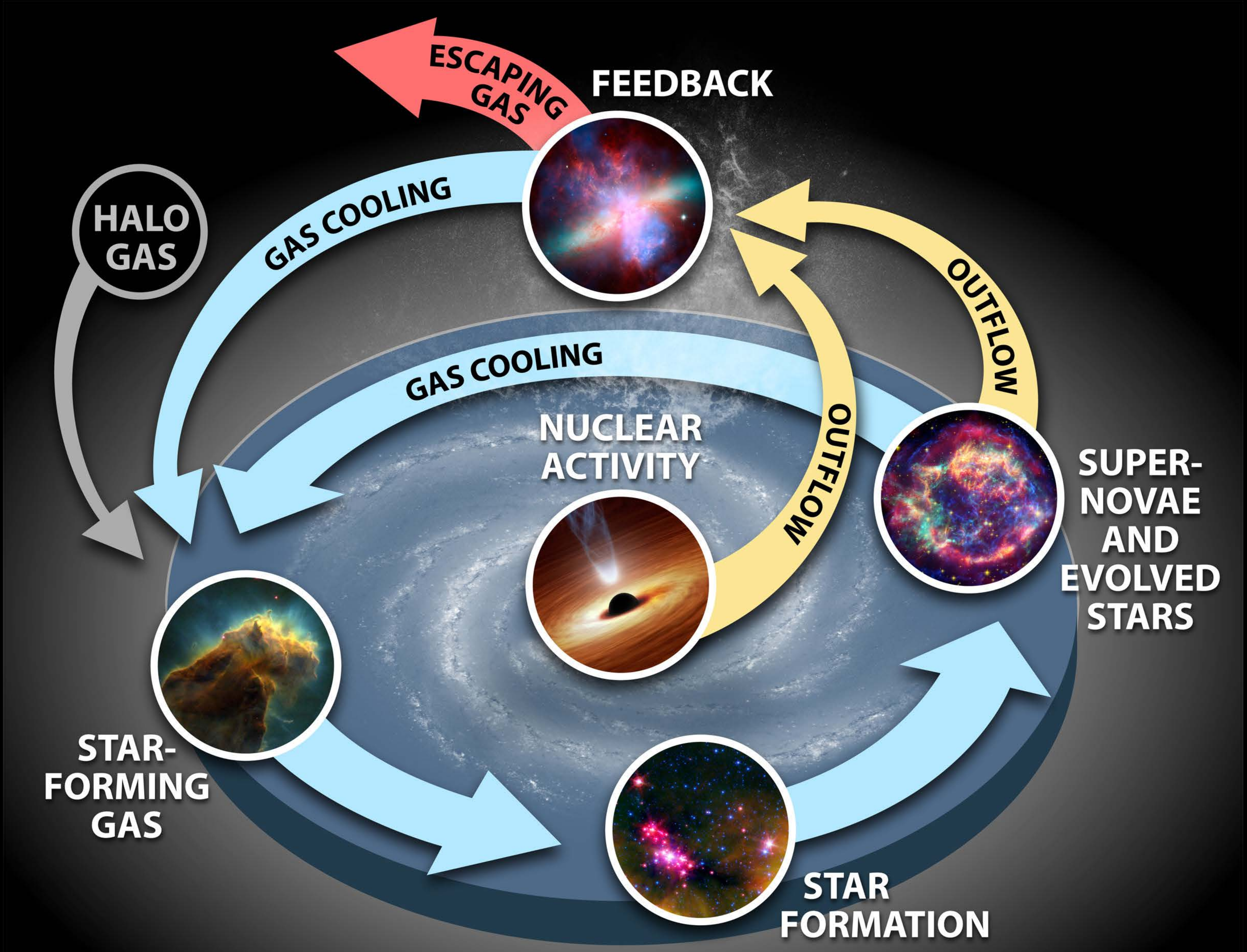
Herschel 2-D surveys are confusion limited…

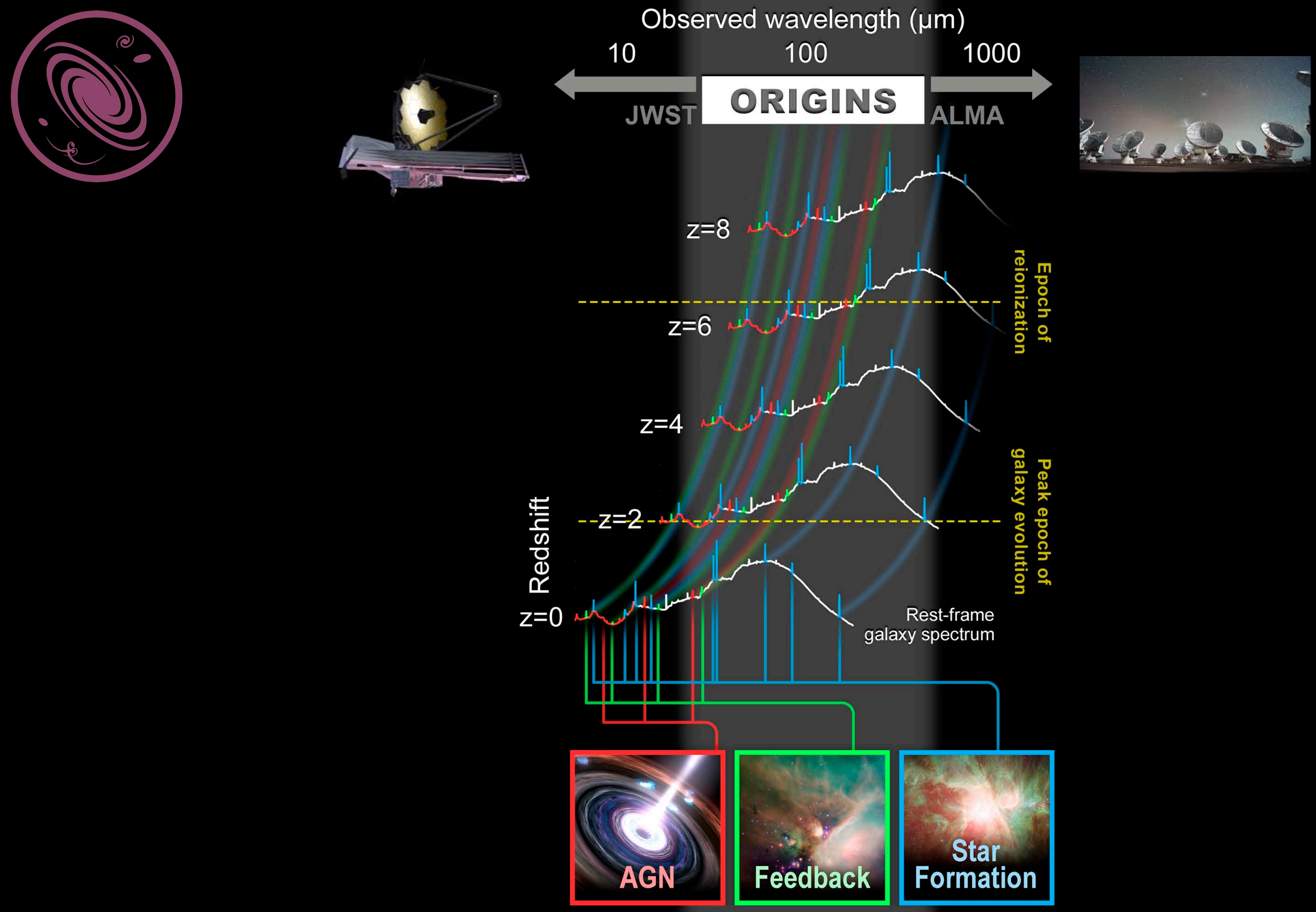


Origins/OSS surveys are not:
“Infrared SDSS”
Millions of galaxies z<8

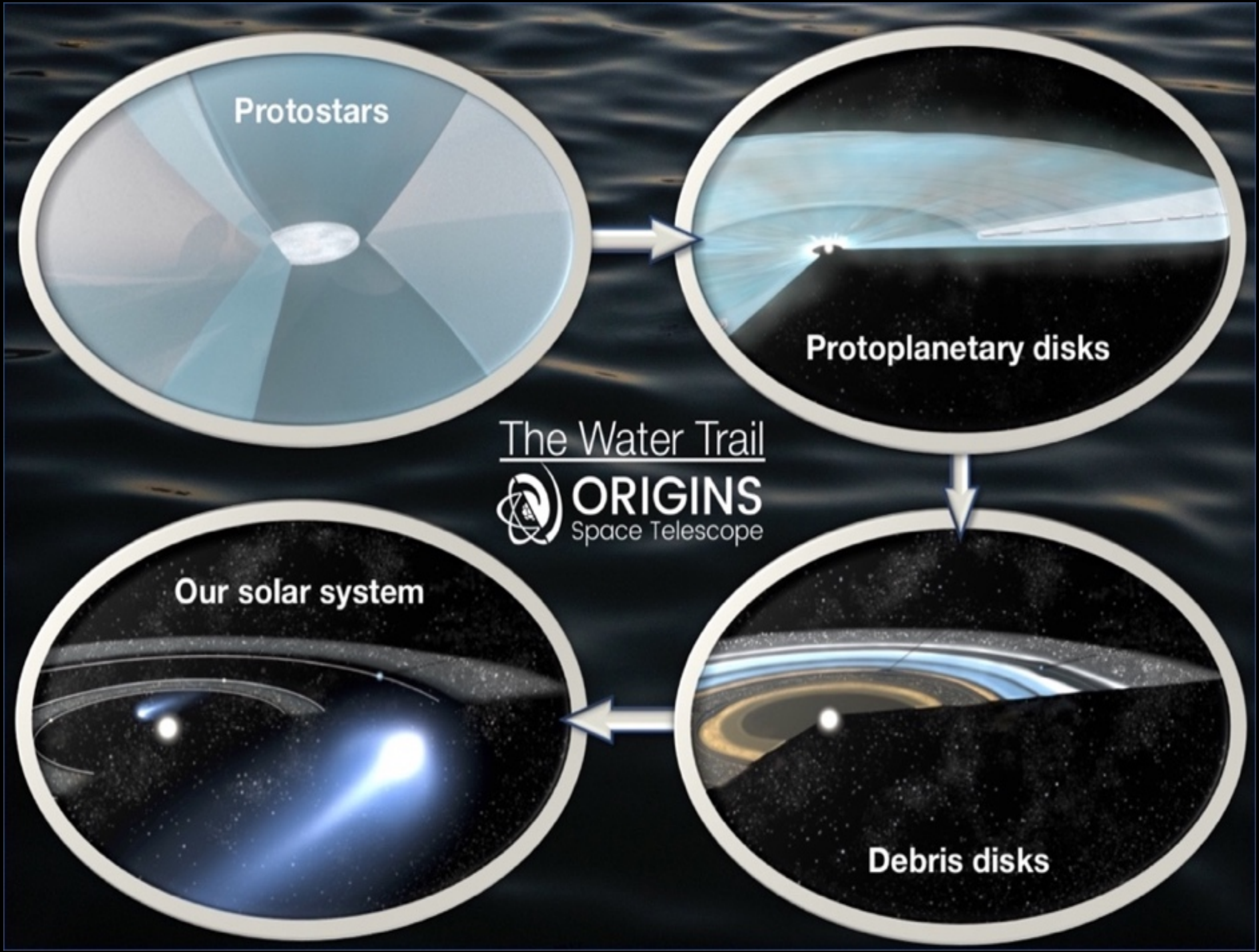
3.6°

Herschel HerMES: Amblard et al.

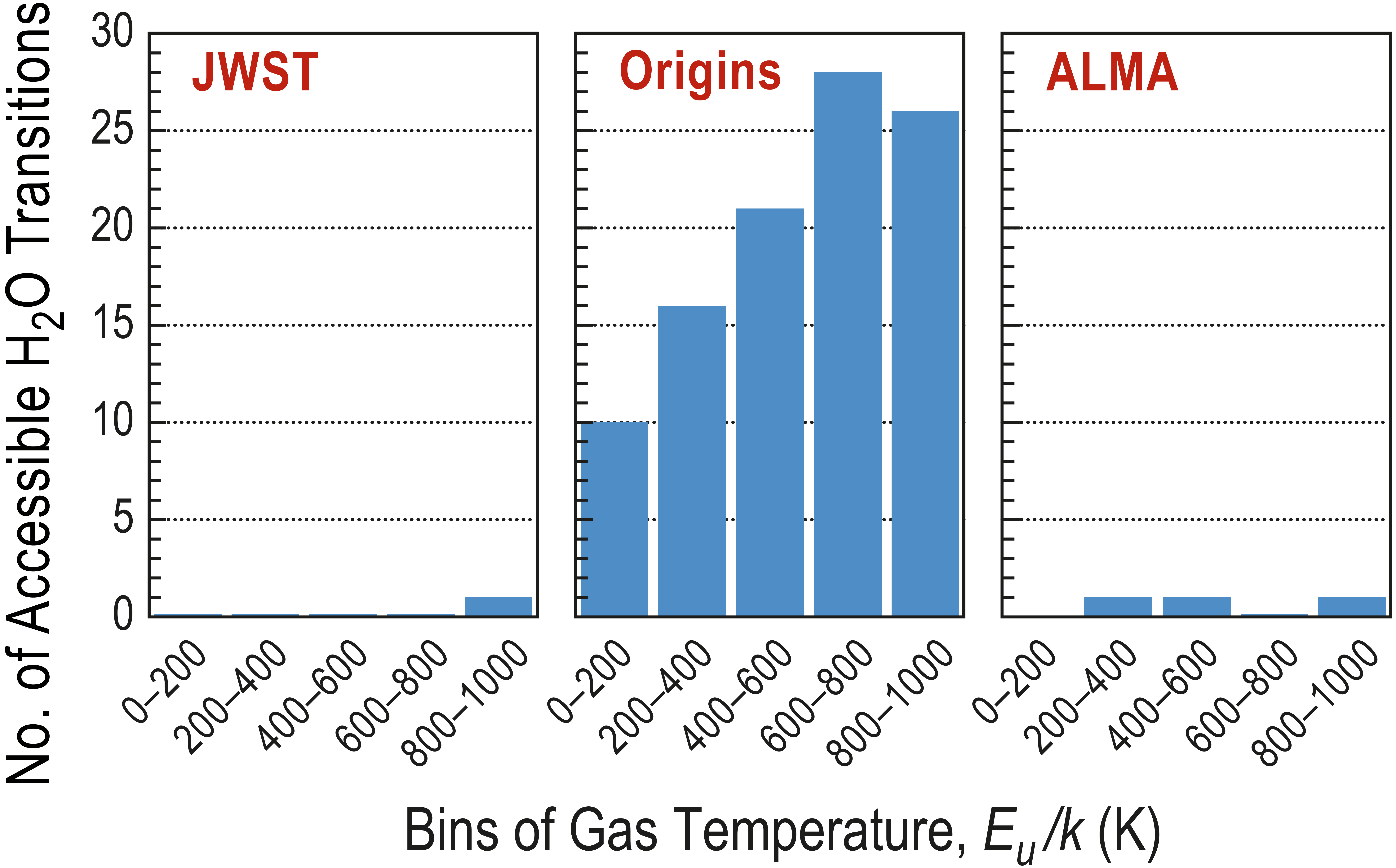

ESCAPING GAS
FEEDBACK
HALO GAS
GAS COOLING
GAS COOLING
OUTFLOW
OUTFLOW
NUCLEAR ACTIVITY
SUPER-NOVAE AND EVOLVED STARS
STAR-FORMING GAS
STAR FORMATION



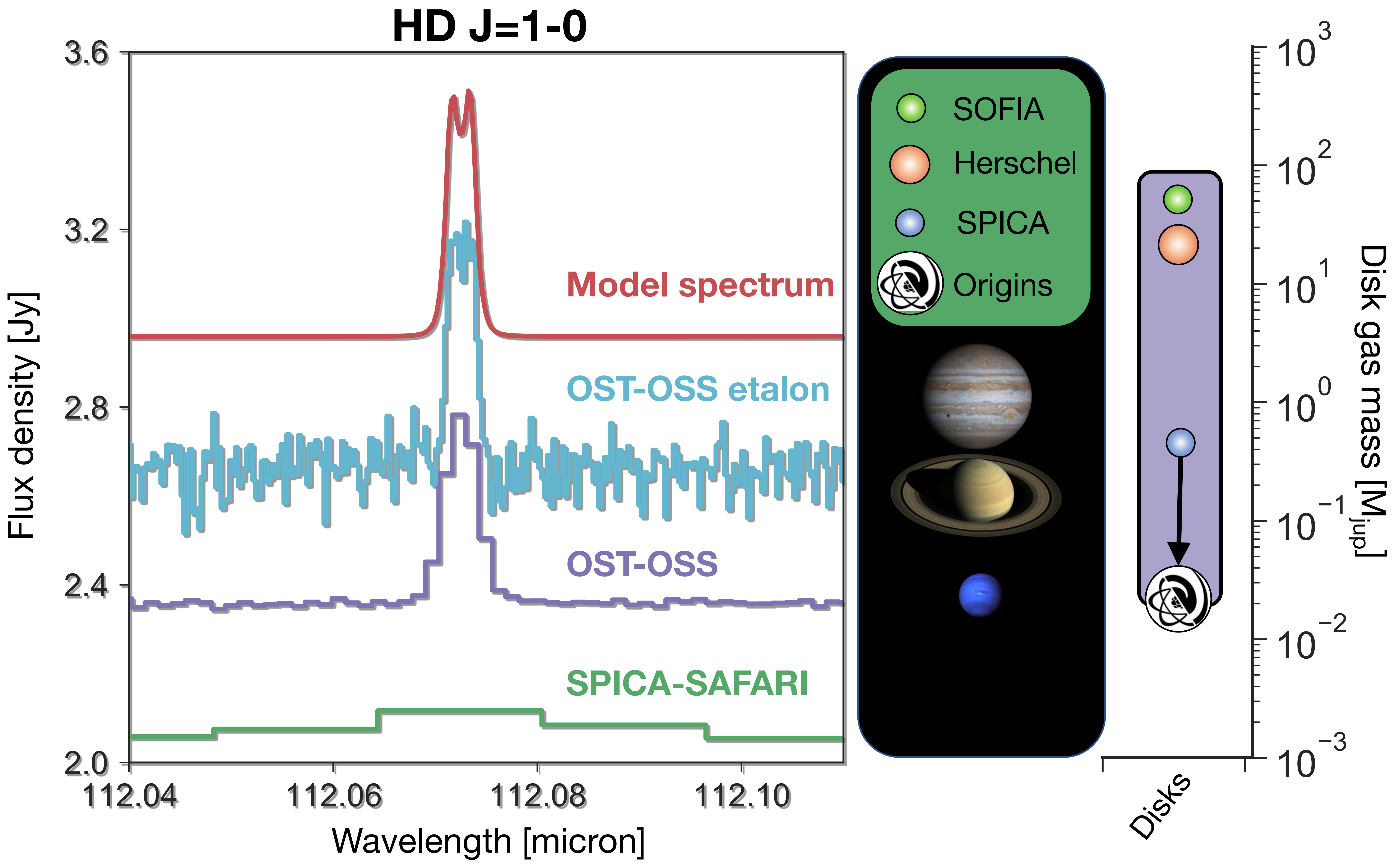
Observed wavelength (μm)
10
100
1000
JWST
ORIGINS
ALMA
z=8
z=6
z=4
z=2
z=0
Redshift
Epoch of reionization
Peak epoch of galaxy evolution
Rest-frame galaxy spectrum
AGN
Feedback
Star Formation


Protostars
Protoplanetary disks
The Water Trail
ORIGINS
Space Telescope
Our solar system
Debris disks

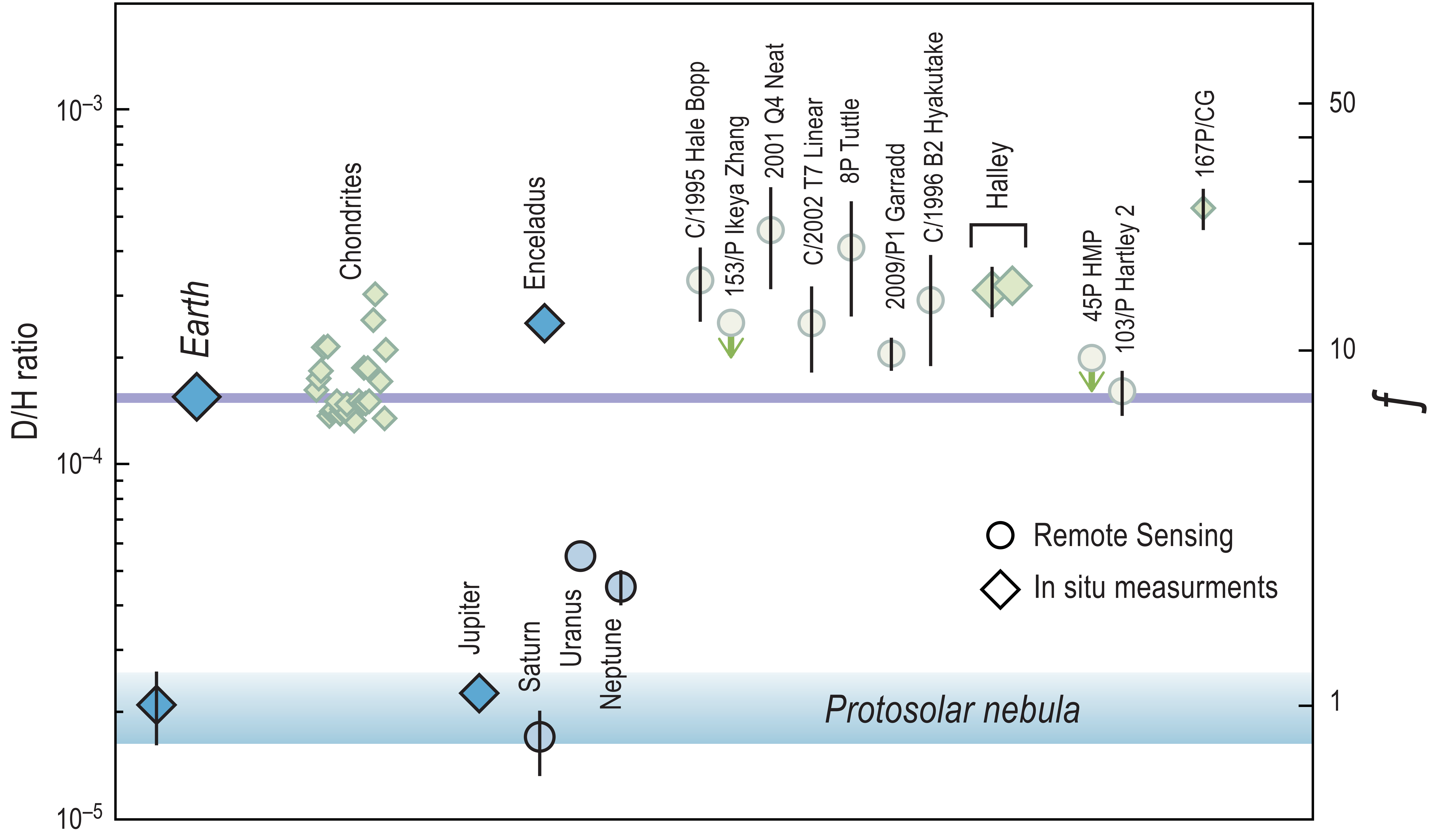
Origins Uniquely Follows the Trail of Water



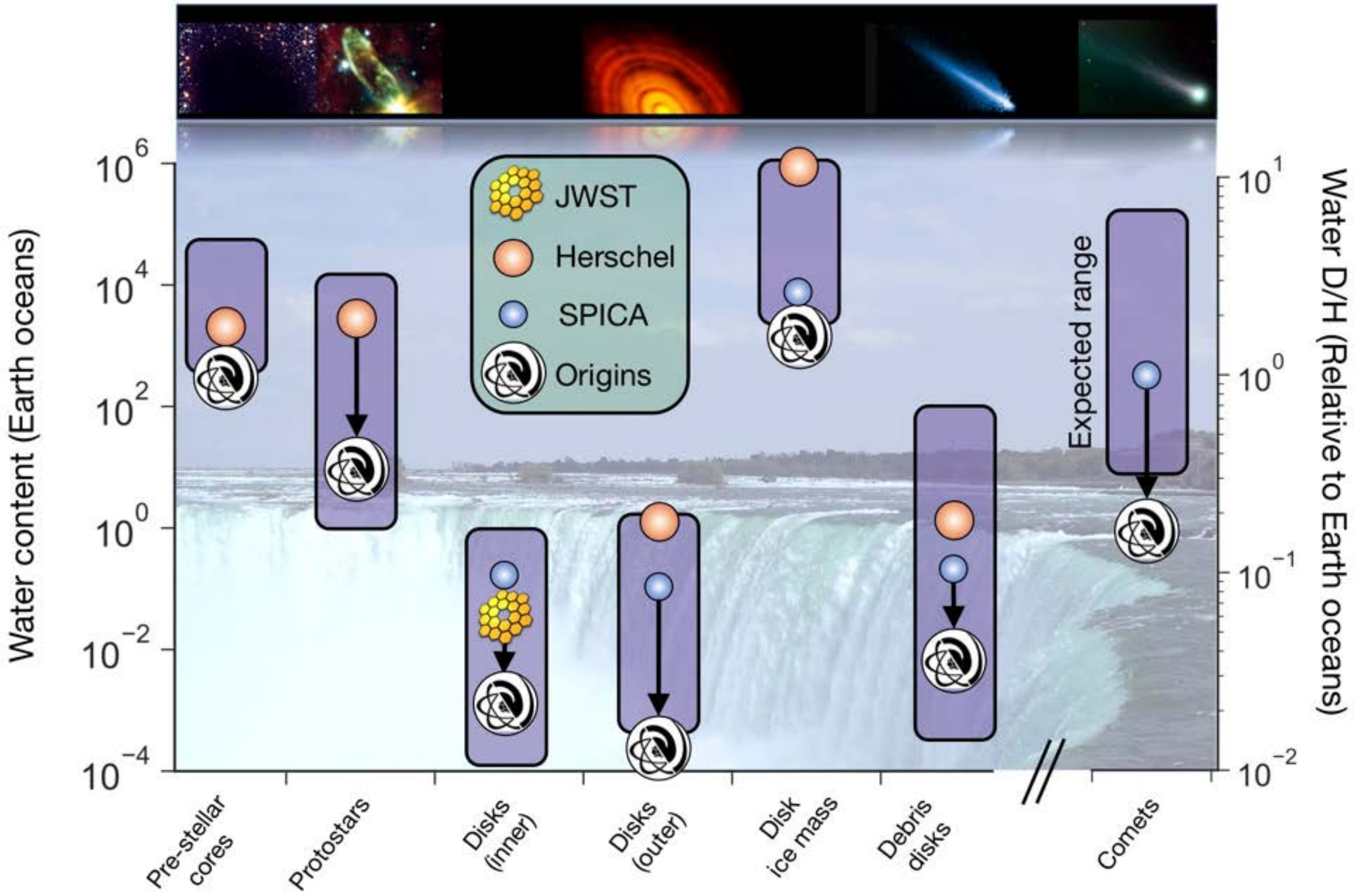
Origins definitively measures gas mass of planet forming disks



Origins definitively measures D/H (HDO/H2O) in >200 comets & asteroids

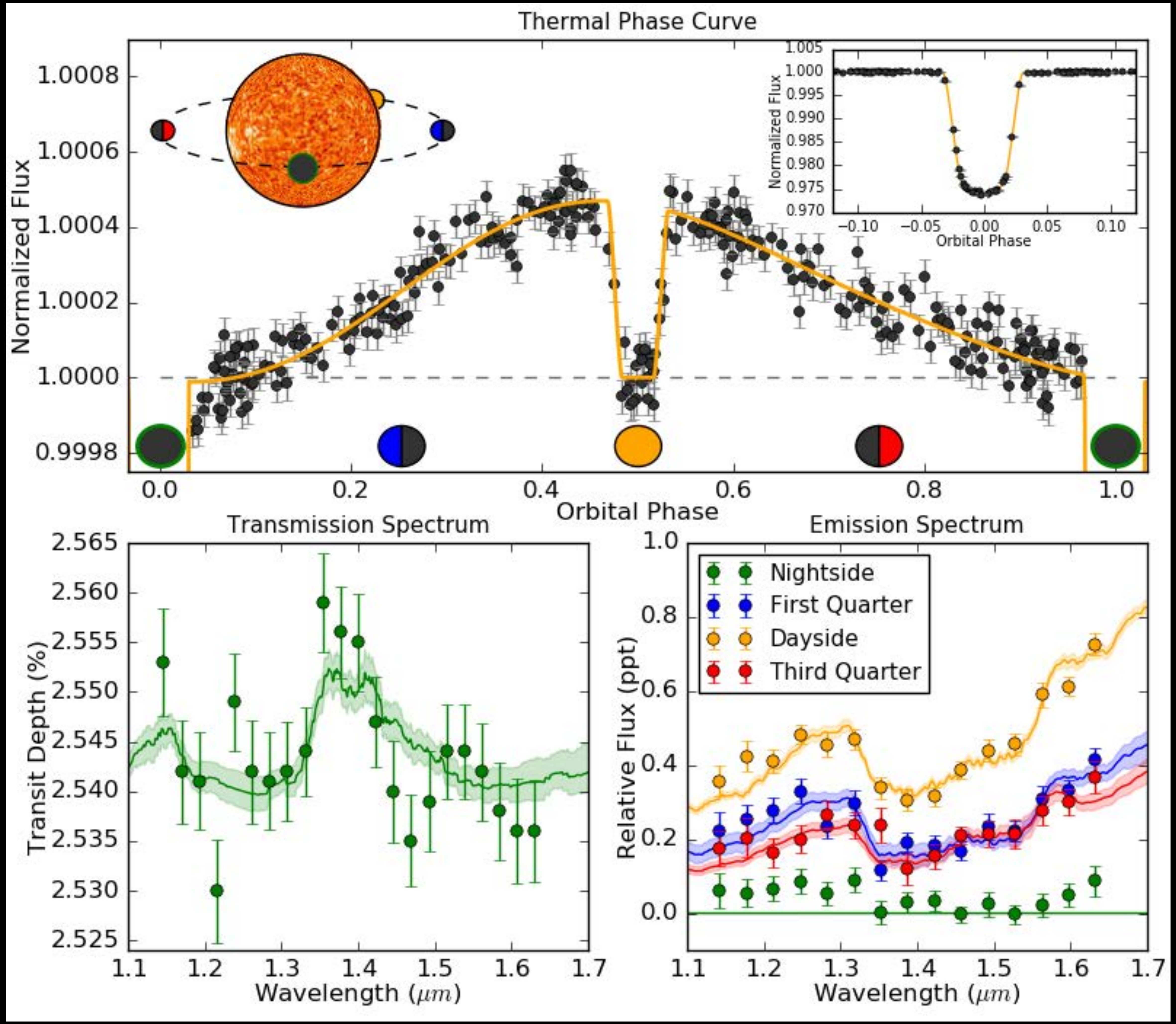


Origins definitive measurements of water trail



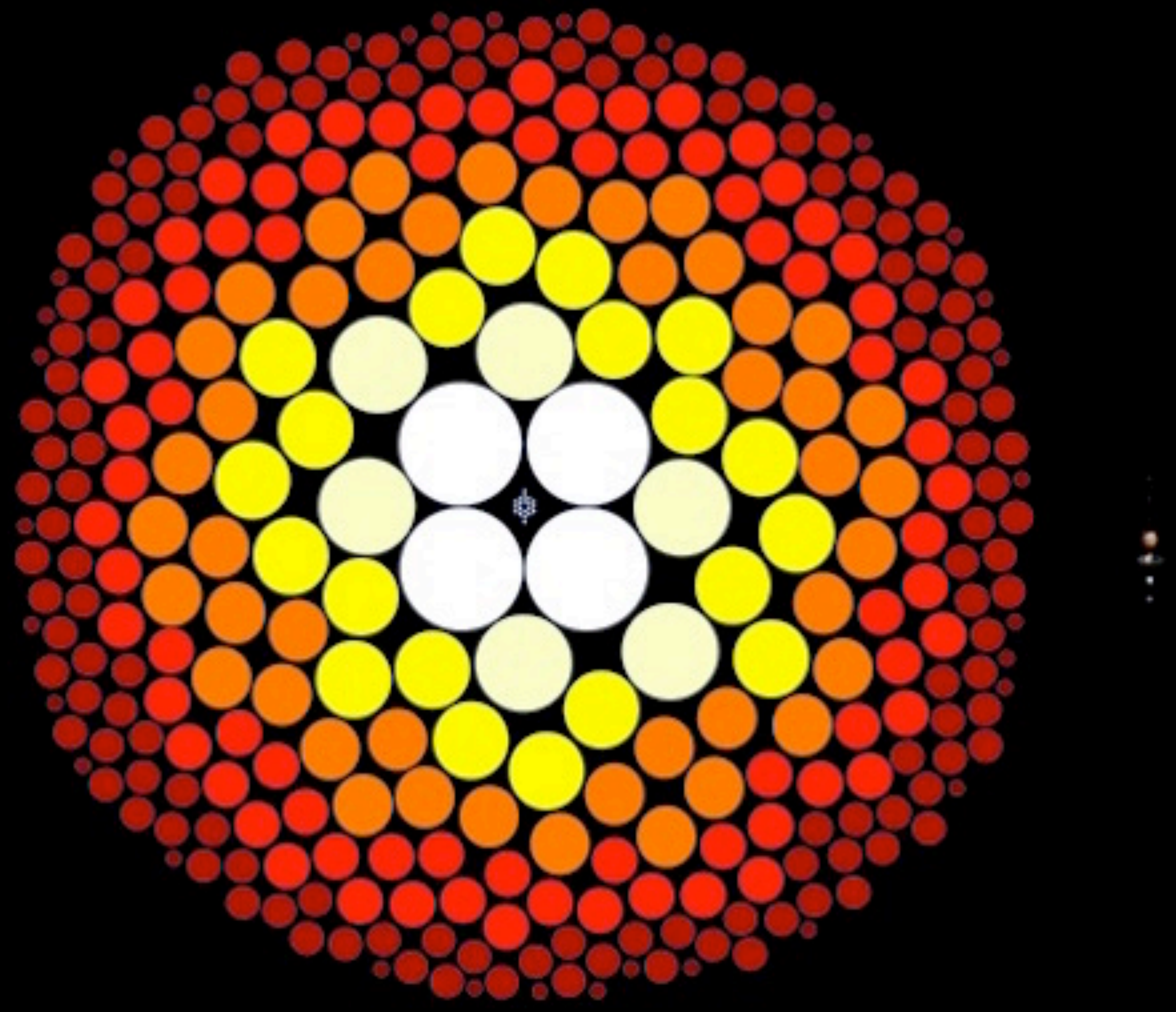
Geometry of Transiting Exoplanets

- Primary Transits
  - Phase = 0 & 1
  - Transmission spectrum
- Secondary Eclipses
  - Phase = 0.5
  - Dayside emission spectrum
- Thermal Phase Curves
  - Phase = 0 to 1
  - Phase-resolved emission spectrum



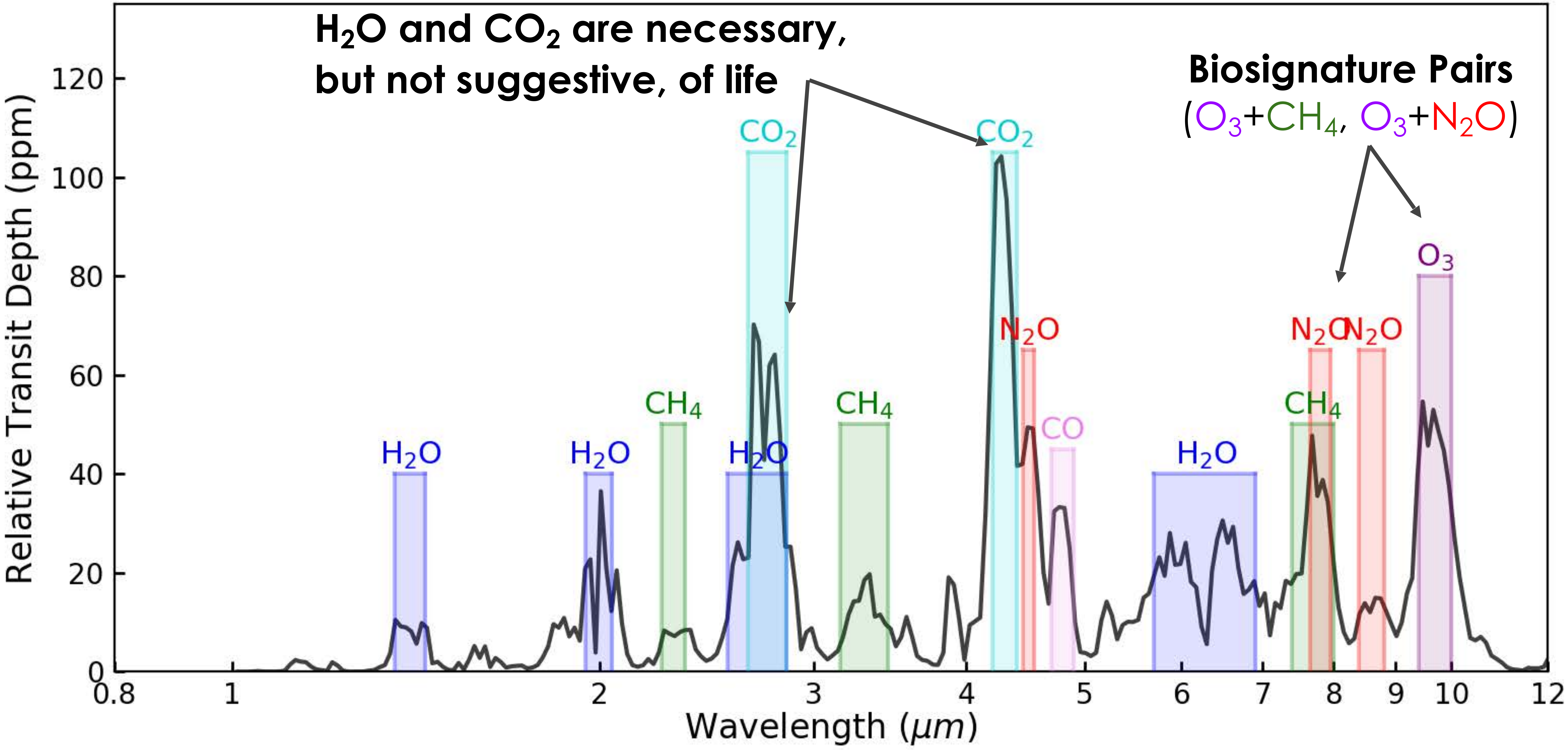
Why M Dwarfs?

- M dwarfs are common
  - 75% of stars within 15 pc are M dwarfs
- Rocky planets are common
  - Expect to detect about a dozen HZ exoplanets transiting mid-to-late M dwarfs within 15 pc
  - Four such planets are already known (TRAPPIST-1d,e,f and LHS-1140b)
- Advantages of small (rocky) planets transiting M dwarf stars
  - Larger transit depths
  - Closer habitable zones (5 – 100 days)
  - Increased transit probability in HZ



T. Henry, RECONS Survey

Origins MISC-T: IR wavelengths rich in biologically interesting molecules



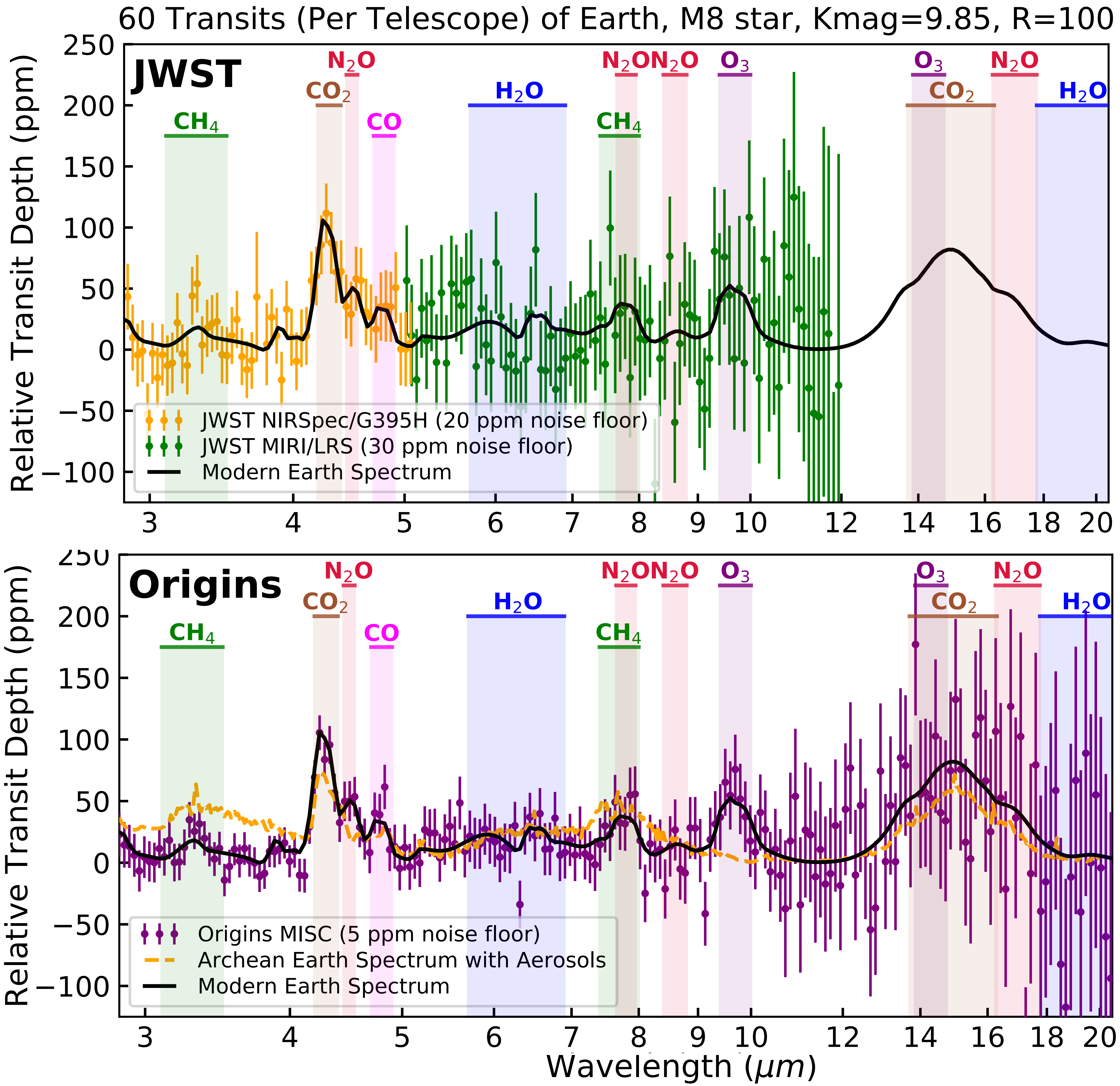
Origins builds on JWST and ELT successes

Tier 3
Search for bio-signatures (O_3+N_2O, O_3+CH_4) with additional transits of temperate worlds

Tier 2
Eclipse observations of clear planets to determine if they are temperate

Tier 1
Transit observations to determine which planets have tenuous, clear or cloudy atmospheres

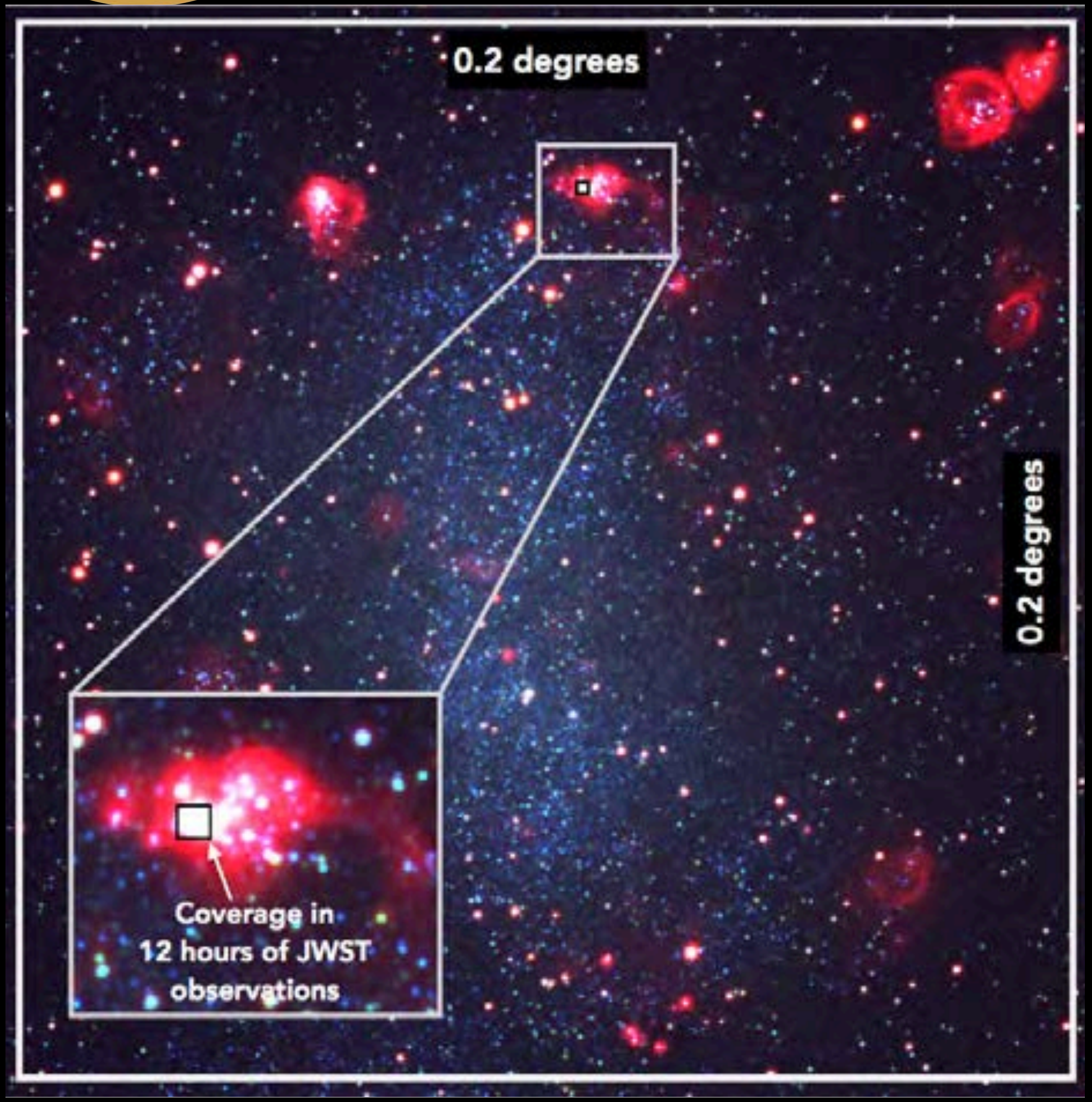
Pre-select terrestrial M-dwarf planets based on: (i) Planet radius and equilibrium temperature.
(ii) Relative rank based on suitability for detailed atmospheric characterization.
(iii) Pre-*Origins* observations with JWST, ELTs etc.



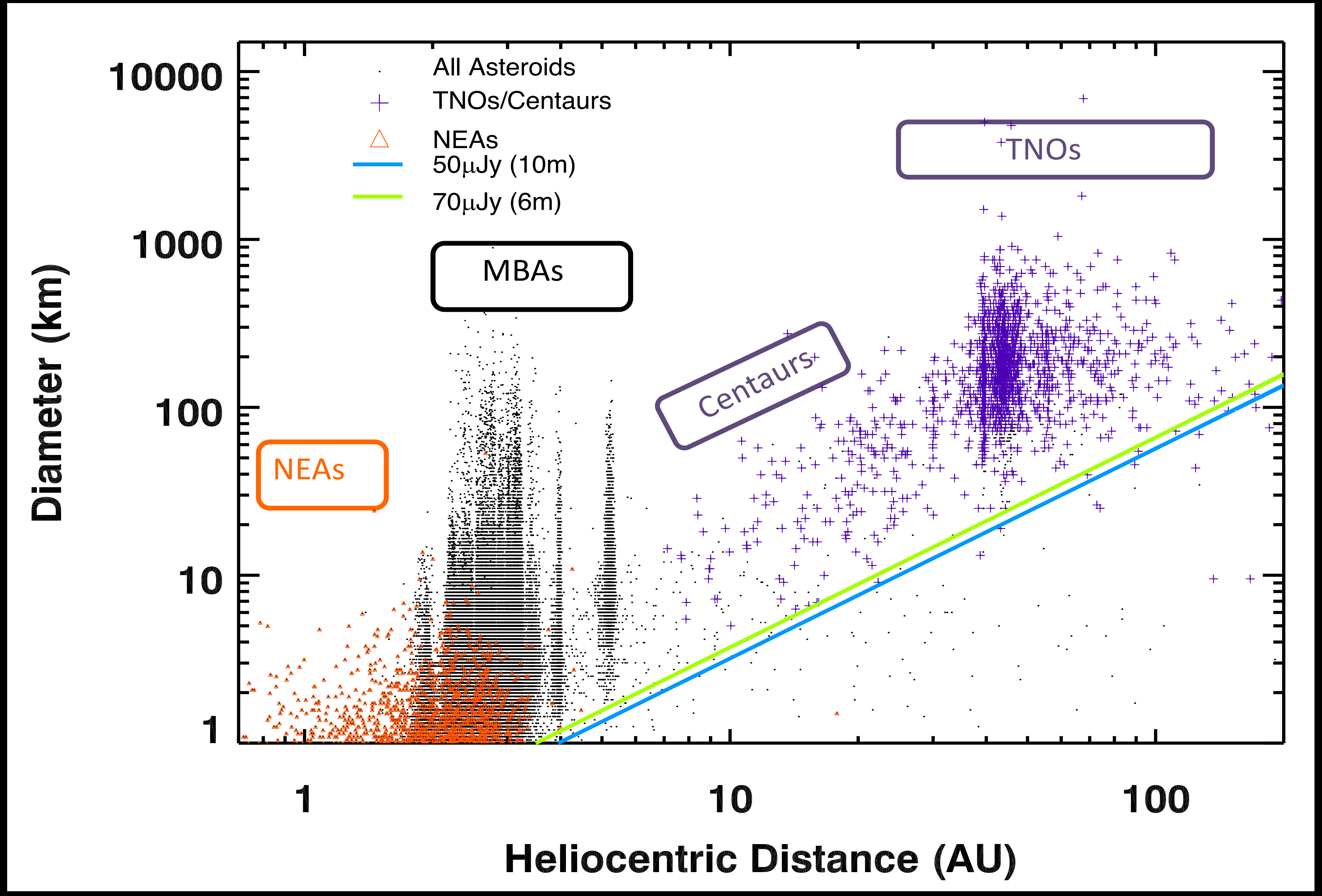
60 Transits (Per Telescope) of Earth, M8 star, Kmag=9.85, R=100
JWST
Origins
CH4
CO2
N2O
CO
H2O
O3
JWST NIRSpec/G395H (20 ppm noise floor)
JWST MIRI/LRS (30 ppm noise floor)
Modern Earth Spectrum
Origins MISC (5 ppm noise floor)
Archean Earth Spectrum with Aerosols
Relative Transit Depth (ppm)
Wavelength (μm)

Discovery Space of Origins

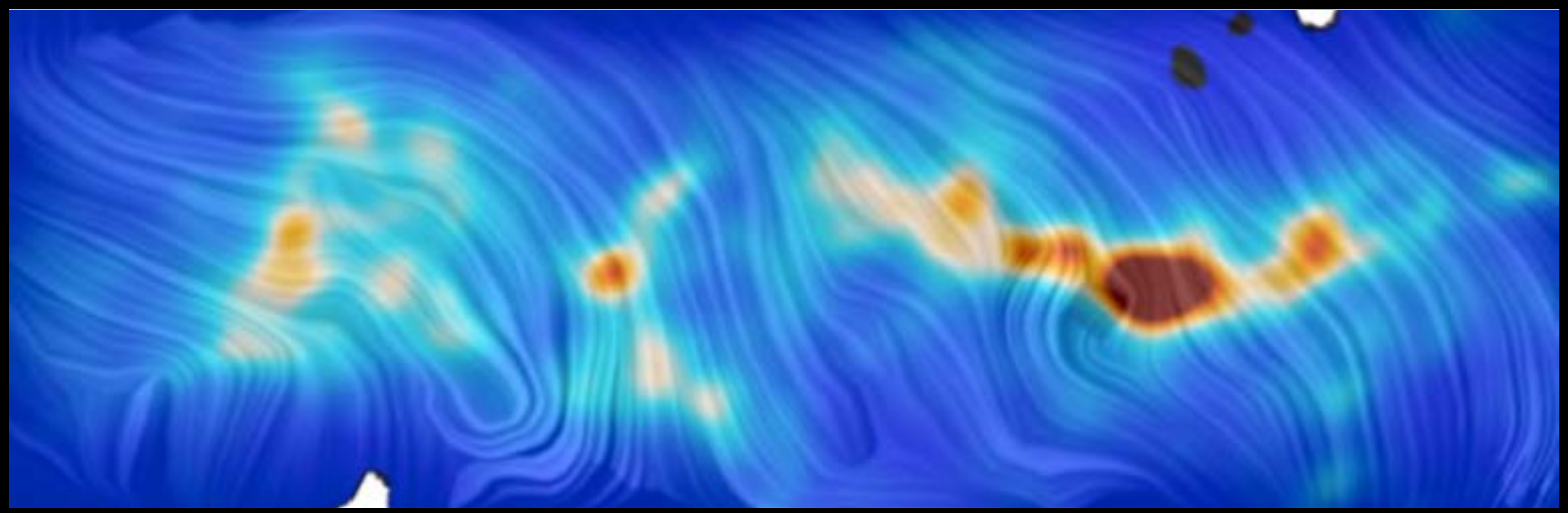
Expectations from modern astrophysics



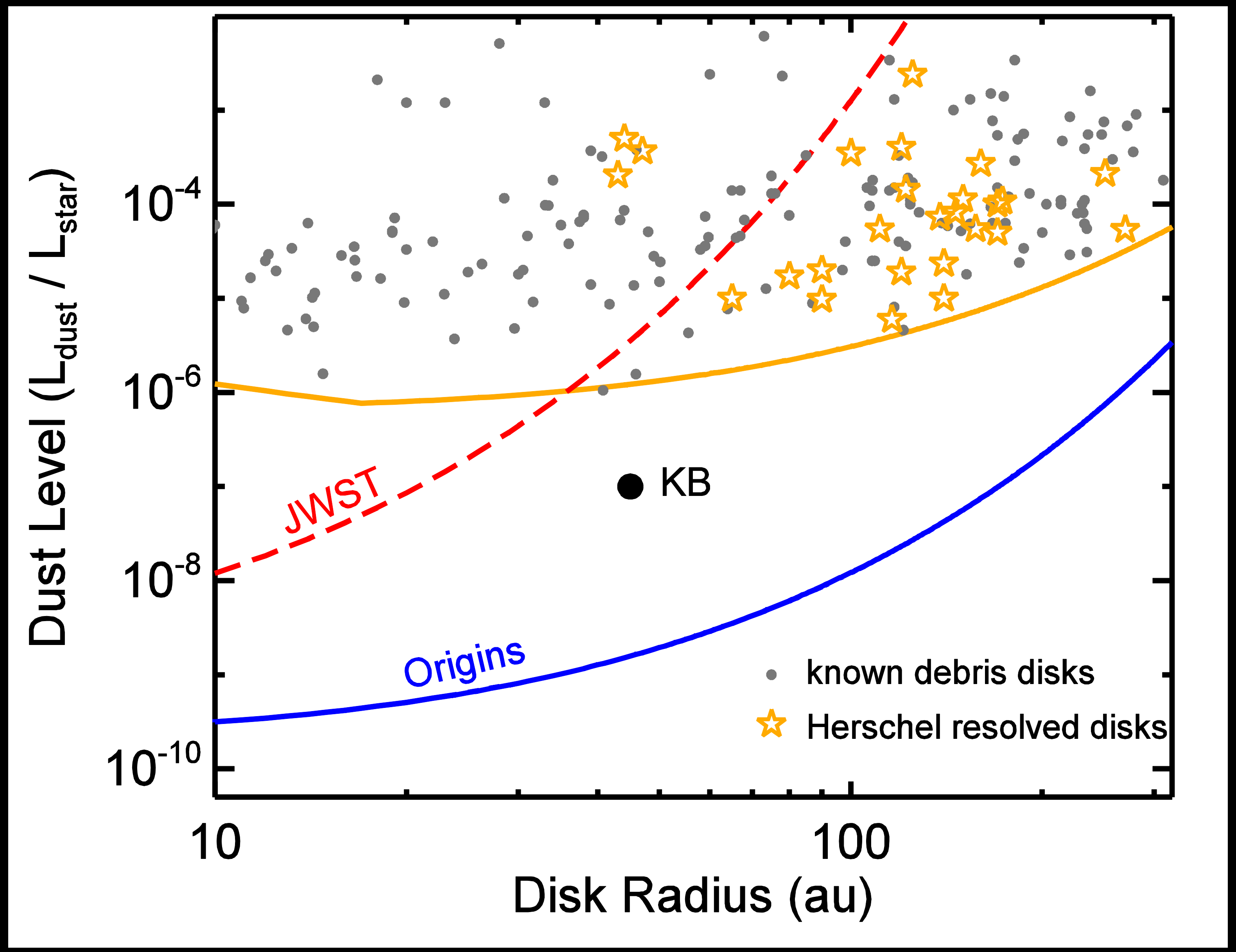
H2 mapping with Origins vs JWST in near-by galaxies (in 12 hours)



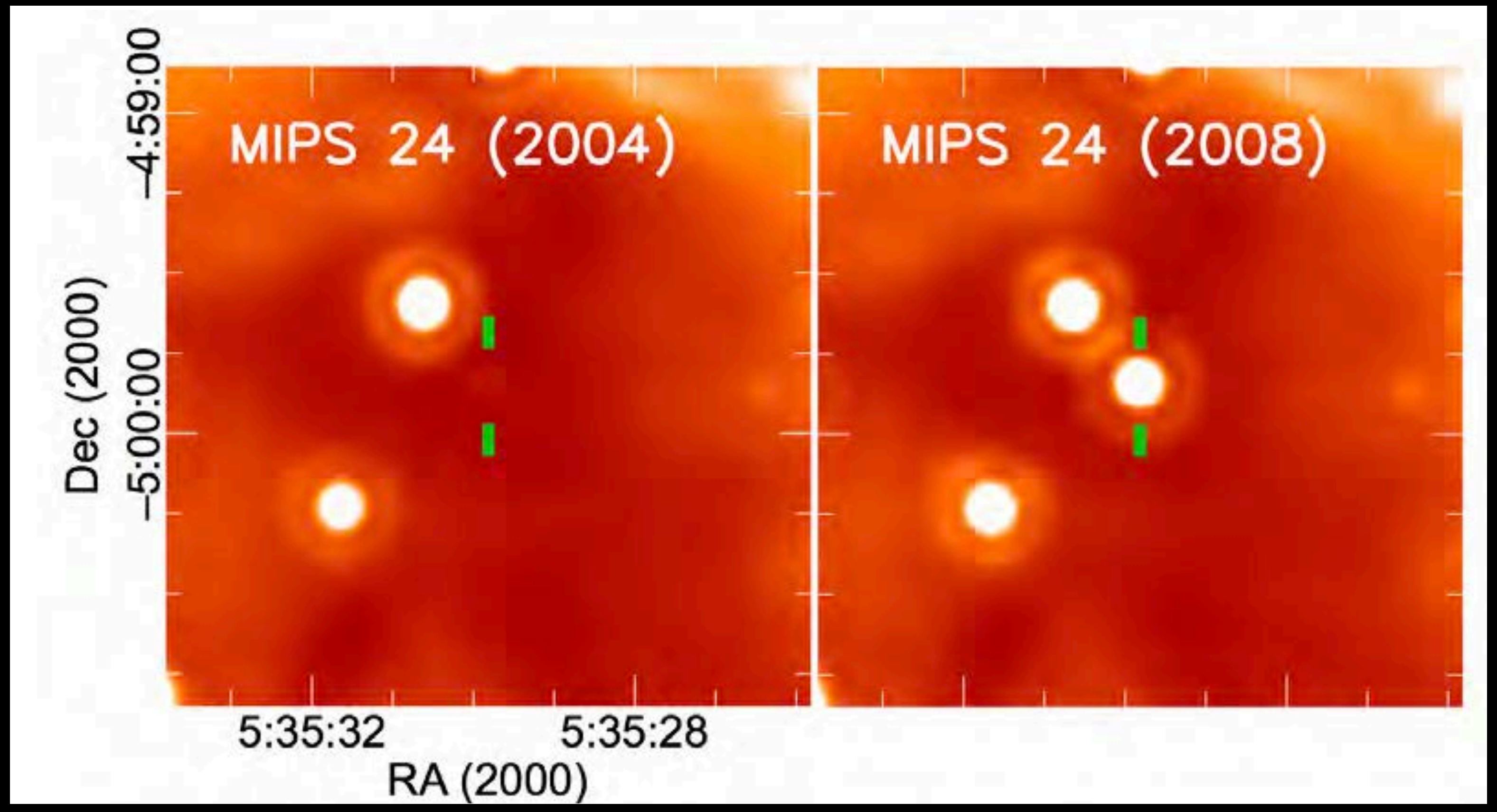
Measure sizes to all KBOs > 10 km in a few hundred hour survey



15" scale maps of dust polarization to bridge Planck (2') & ground (1")



Study dust in debris disks!



Time variability in protostellar accretion *(Time-domain panel)*

And lots and lots more!

Thanks to Origins Study Team

Full team list: asd.gsfc.nasa.gov/firs/

Now is the time to do Origins!

- science drivers are NASA astrophysics:
  - How does the Universe work?, How did we get here?, Are we alone?
- Vast Discovery space
- x1000 in sensitivity
- 4.5 K, 5.9 m telescope + sensitive Far-IR detectors
- Agile observatory mapping 1000s deg^2
- exoplanet transit spectroscopy high precision 2.8-20 μm spectrograph, <5 to 20 ppm
- Builds on technical heritage, e.g. Herschel
- Origins' design is low-risk (minimal deployments) and robust.
- Technology maturation is achievable (3-4 years).
  - https://origins.ipac.caltech.edu
  - https://asd.gfsc.nasa.gov/firs/