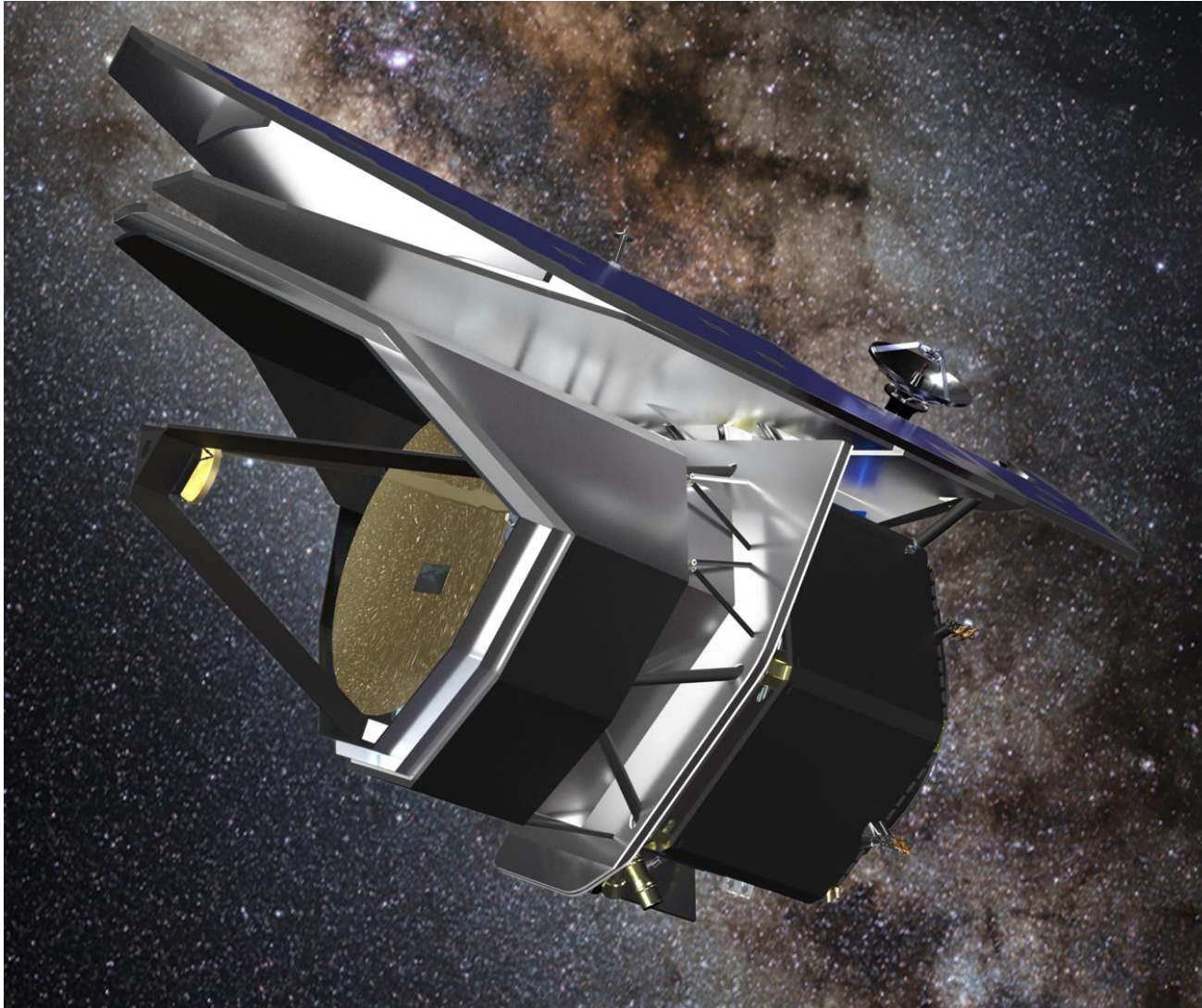




*The PProbe far-Infrared
Mission for Astrophysics*

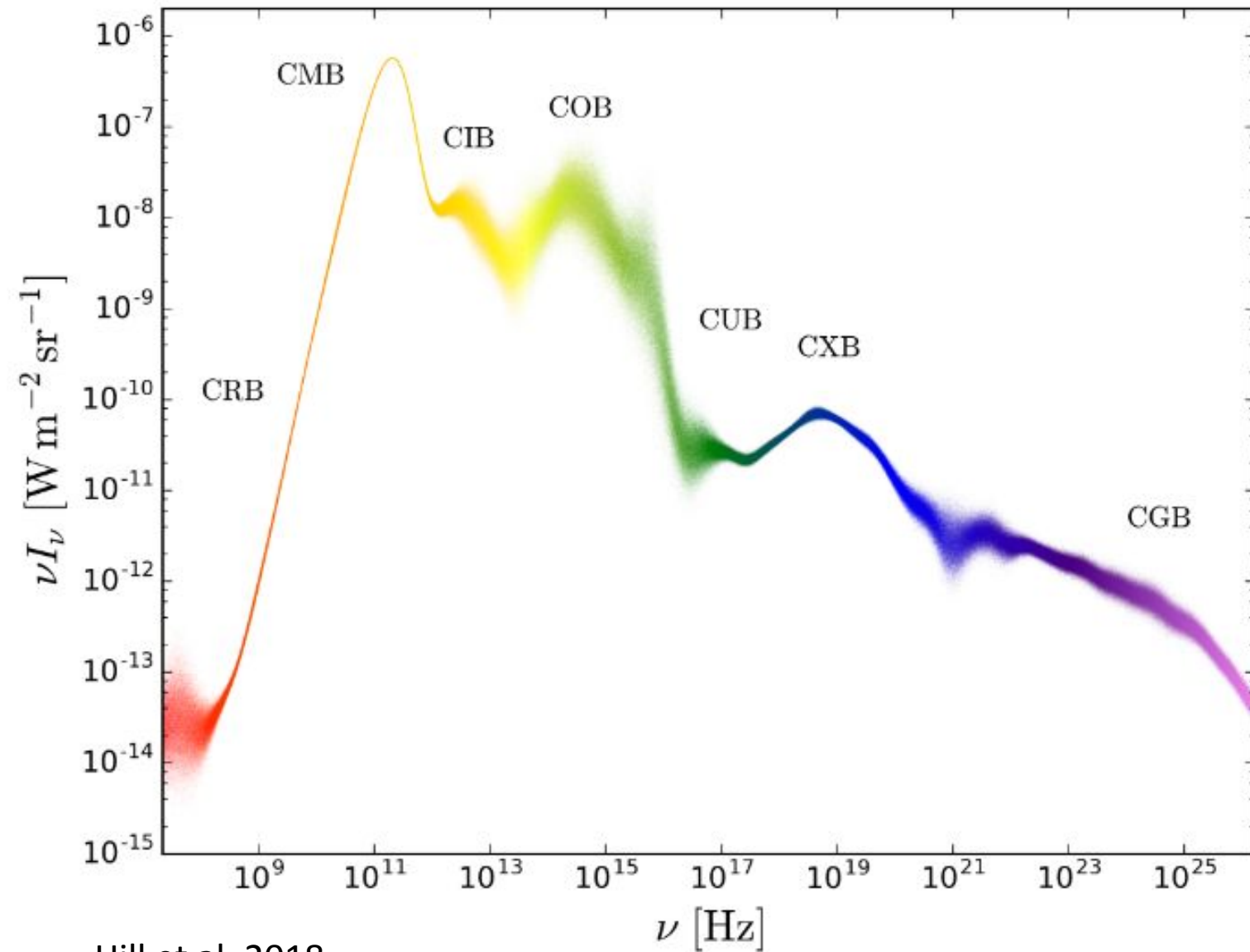


prima.ipac.caltech.edu/

Alexandra Pope
University of Massachusetts
Amherst
Co-I and Science Lead for PRIMA

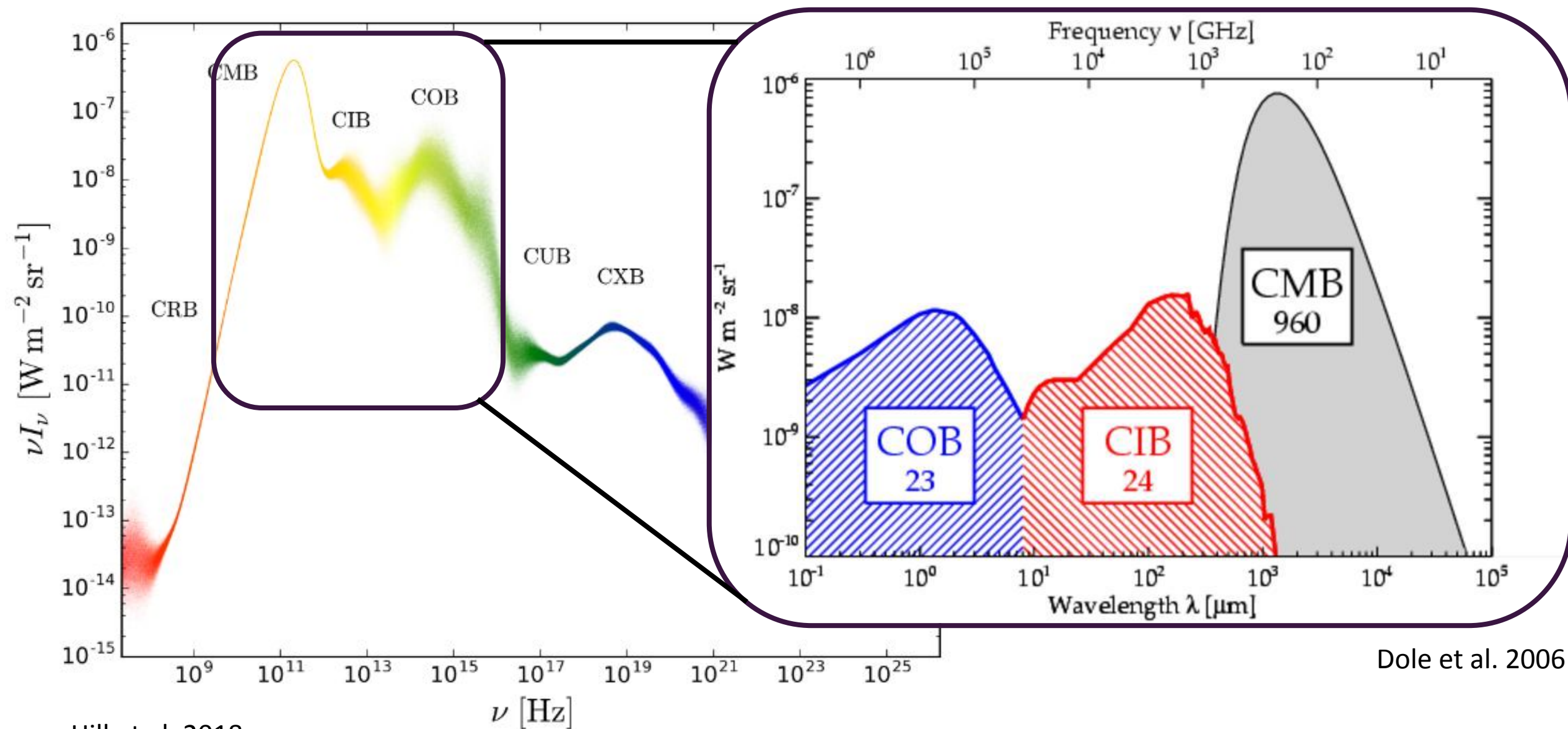
UMass/FCAD Colloquium
February 26, 2026

The Spectrum of the Universe



Hill et al. 2018

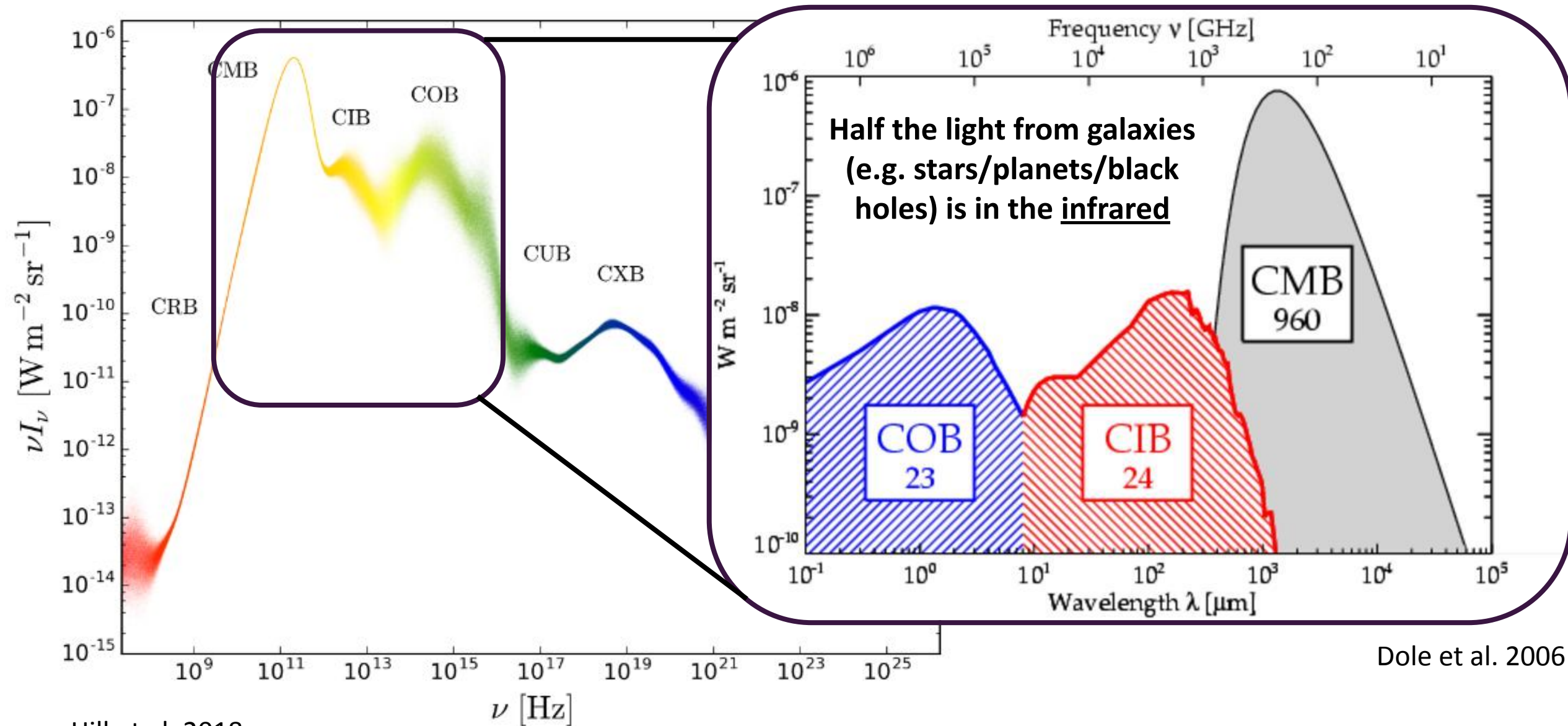
The Spectrum of the Universe



Hill et al. 2018

Dole et al. 2006

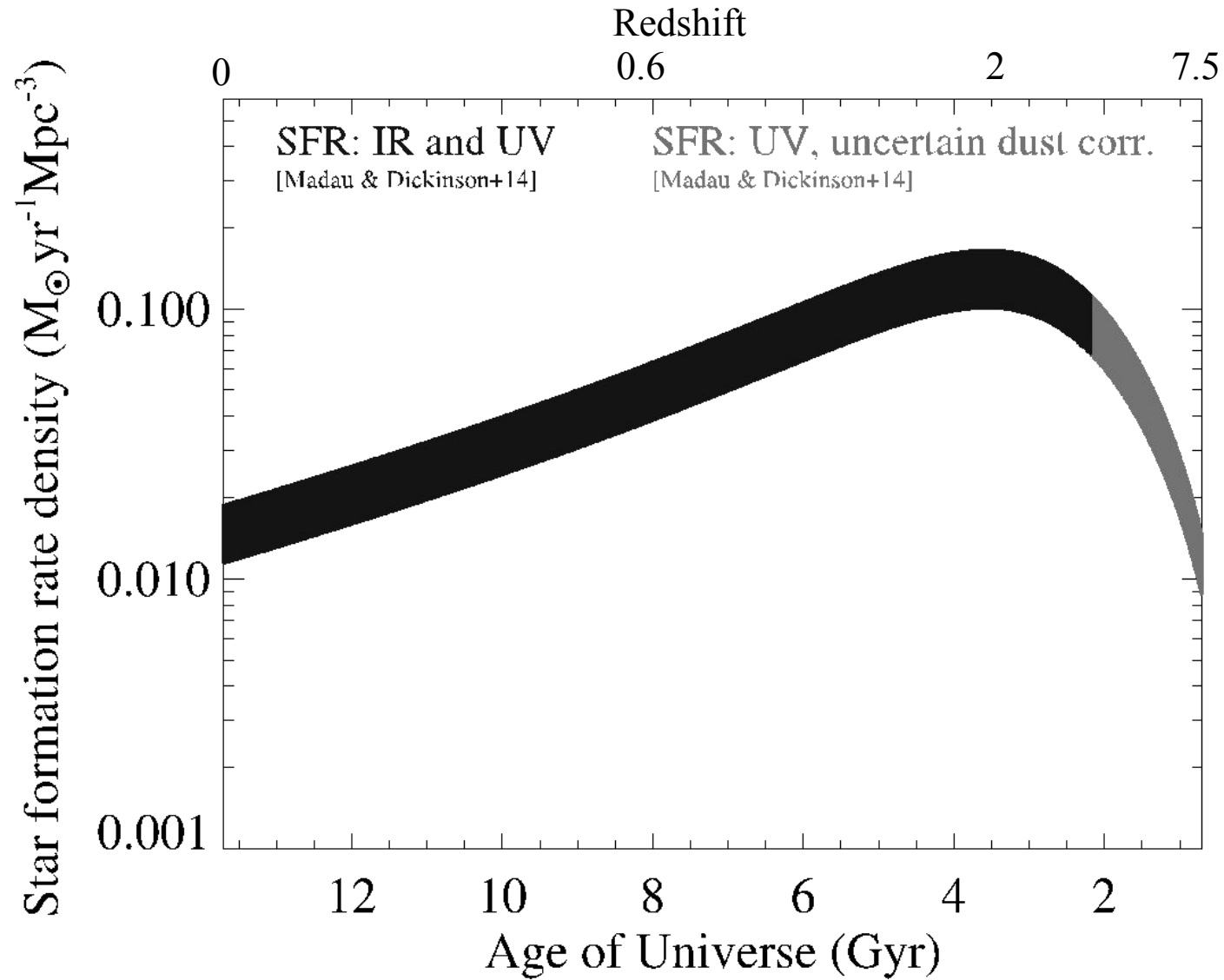
The Spectrum of the Universe



Dole et al. 2006

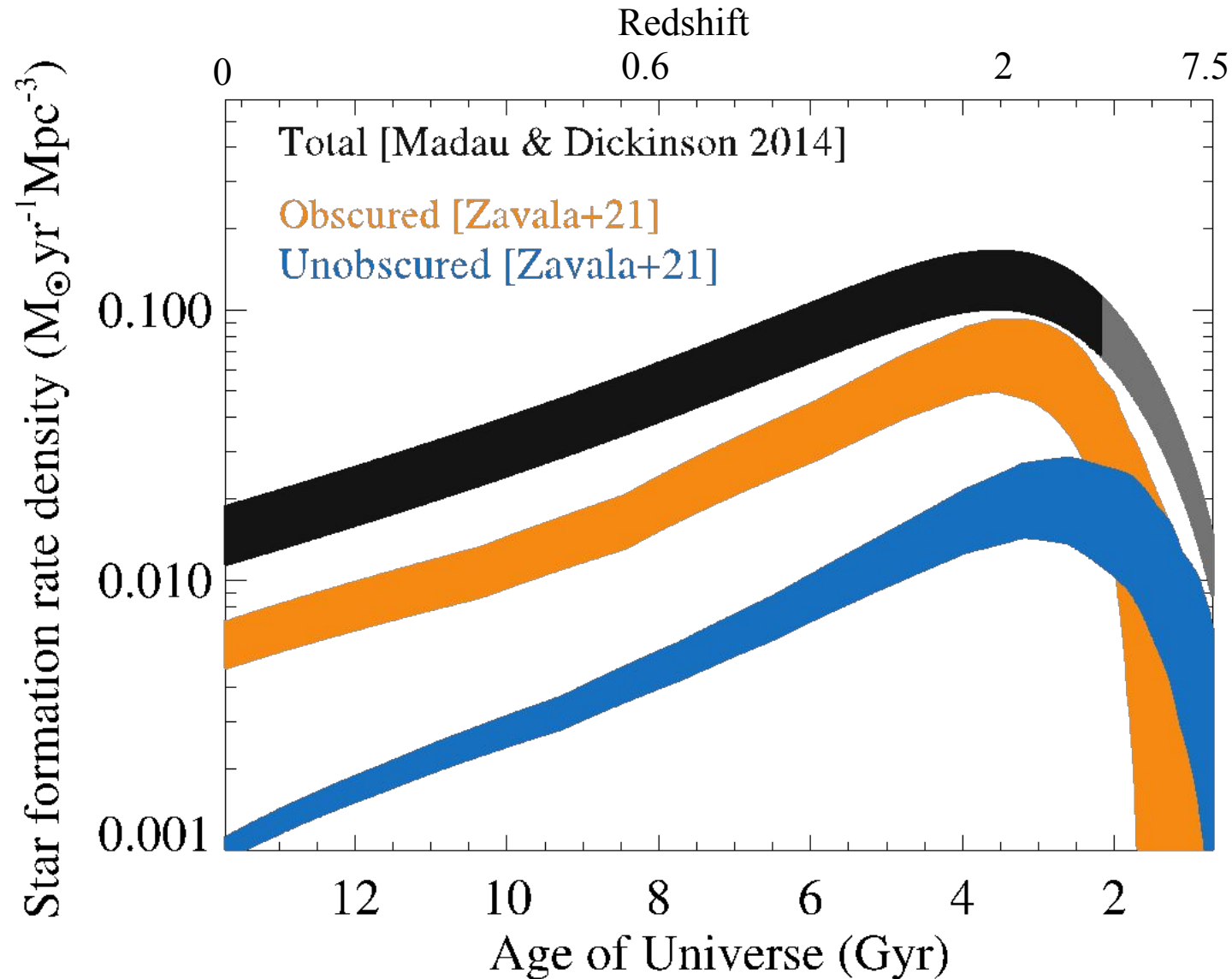
Hill et al. 2018

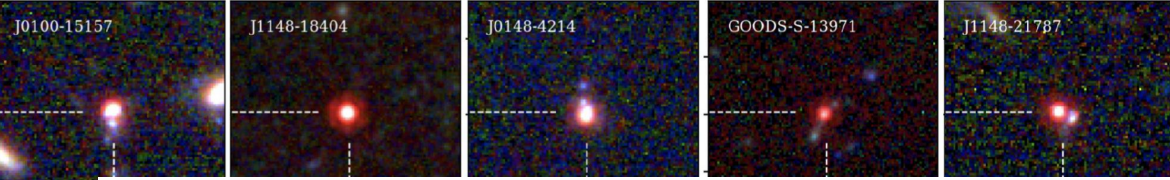
What about the light from star formation?



What about the light from star formation?

The majority is obscured (detected in the infrared)



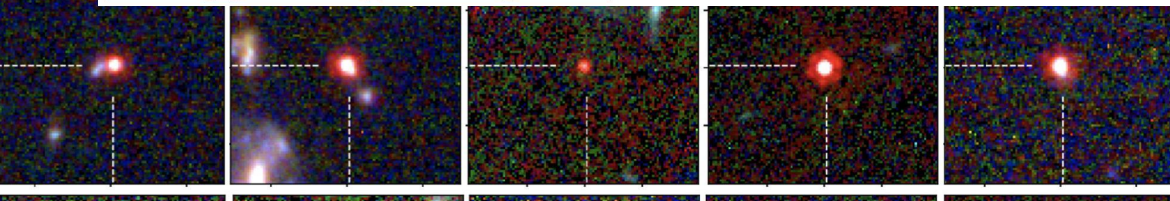


Little Red Dots: An Abundant Population of Faint Active Galactic Nuclei at $z \sim 5$ Revealed by the EIGER and FRESCO JWST Surveys

Jorryt Matthee^{1,2} , Rohan P. Naidu^{23,3} , Gabriel Brammer⁴ , John Chisholm⁵ , Anna-Christina Eilers³ , Andy Goulding⁶ , Jenny Greene⁶ , Daichi Kashino^{7,8} , Ivo Labbe⁹ , Simon J. Lilly¹ [+ Show full author list](#)

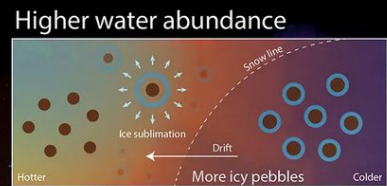
Published 2024 March 7 • © 2024. The Author(s). Published by the American Astronomical Society.

[The Astrophysical Journal](#), Volume 963, Number 2

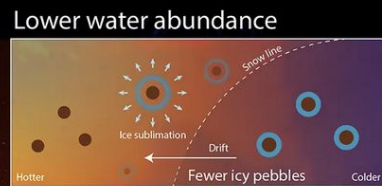


PROTOPLANETARY DISKS ICY PEBBLE DRIFT

MIRI | Medium Resolution Spectroscopy



Compact Disk



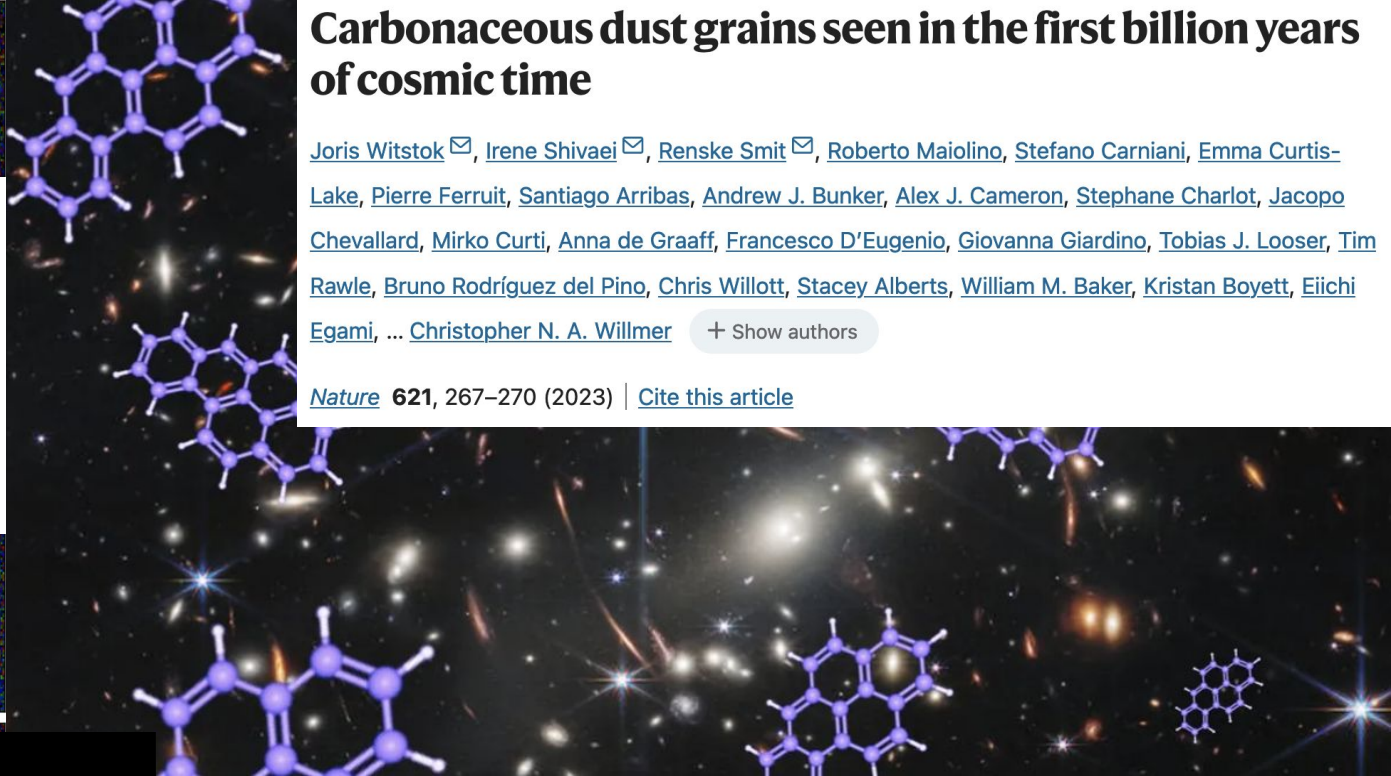
Extended Disk

WEBB
SPACE TELESCOPE

Carbonaceous dust grains seen in the first billion years of cosmic time

Joris Witstok , Irene Shivaie , Renske Smit , Roberto Maiolino, Stefano Carniani, Emma Curtis-Lake, Pierre Ferruit, Santiago Arribas, Andrew J. Bunker, Alex J. Cameron, Stephane Charlot, Jacopo Chevallard, Mirko Curti, Anna de Graaff, Francesco D'Eugenio, Giovanna Giardino, Tobias J. Looser, Tim Rawle, Bruno Rodríguez del Pino, Chris Willott, Stacey Alberts, William M. Baker, Kristan Boyett, Eiichi Egami, ... [Christopher N. A. Willmer](#) [+ Show authors](#)

[Nature](#) **621**, 267–270 (2023) | [Cite this article](#)



JWST Reveals Excess Cool Water near the Snow Line in Compact Disks, Consistent with Pebble Drift

Andrea Banzatti¹ , Klaus M. Pontoppidan² , John S. Carr³ , Evan Jellison¹, Ilaria Pascucci⁴ , Joan R. Najita⁵ , Carlos E. Muñoz-Romero⁷ , Karin I. Öberg⁶ , Anusha Kalyaan¹ , Paola Pinilla⁷ [+ Show full author list](#)

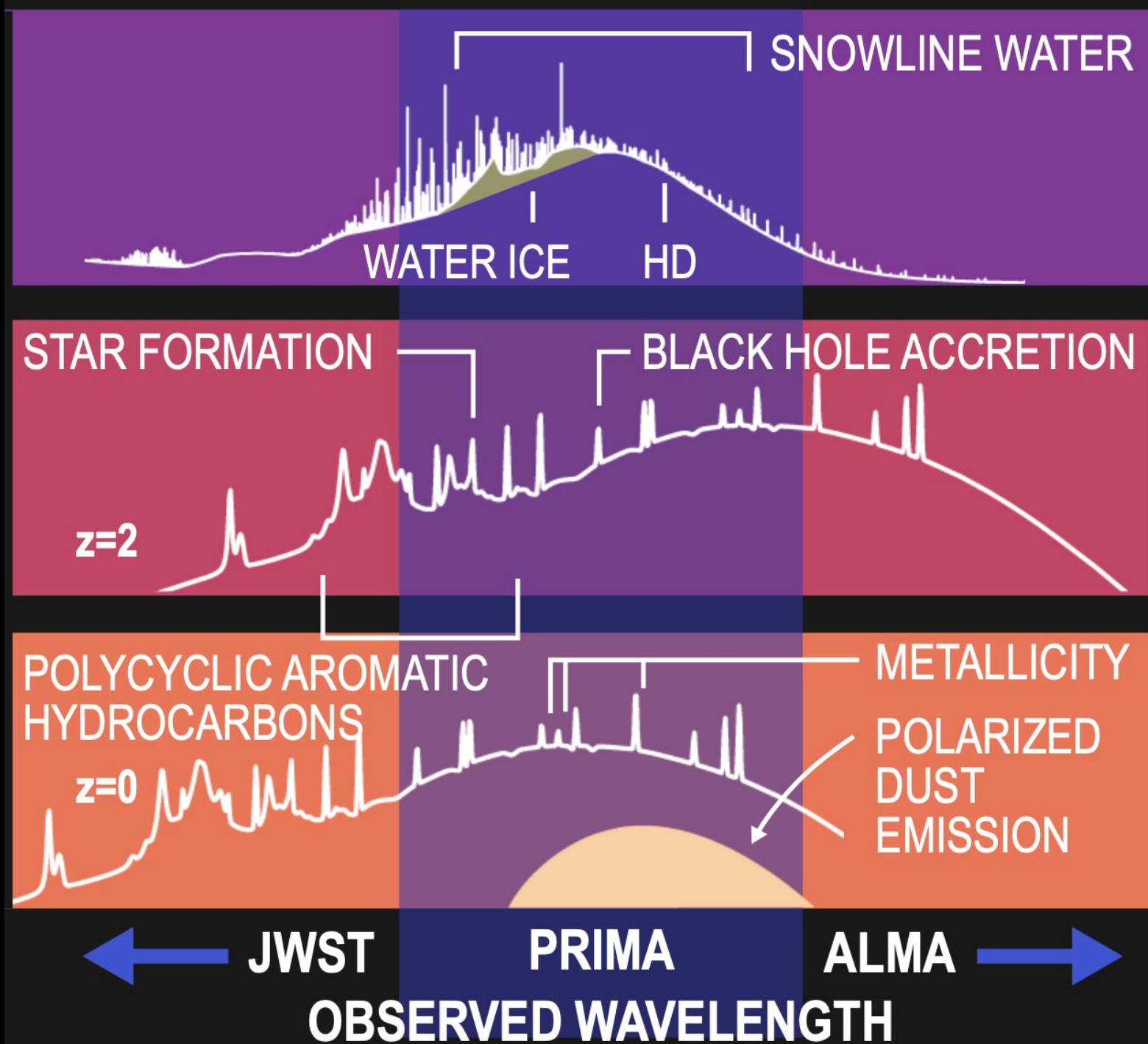
Published 2023 November 8 • © 2023. The Author(s). Published by the American Astronomical Society.

[The Astrophysical Journal Letters](#), Volume 957, Number 2

Planet forming disks

Galaxies and central
supermassive black
holes

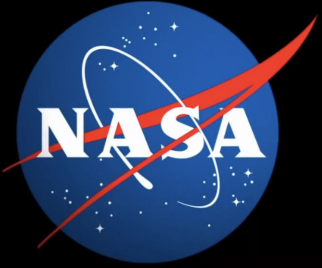
Dust emission in
galaxies



Astro2020 Decadal Survey Section 7.5.3.3 :

and a probe scale mission is an extremely timely and compelling opportunity to do so. These scientific areas include tracing the astrochemical signatures of planet formation (within and outside of our own Solar System), measuring the formation and buildup of galaxies, heavy elements, and interstellar dust from the first galaxies to today, and probing the co-evolution of galaxies and their supermassive black holes across cosmic time. These goals are all central to the broader scientific themes of the survey. The

Astro2020
Decadal Survey
Section 7.5.3.3 :



and a probe scale mission is an extremely timely and compelling opportunity to do so. These scientific areas include tracing the astrochemical signatures of planet formation (within and outside of our own Solar System), measuring the formation and buildup of galaxies, heavy elements, and interstellar dust from the first galaxies to today, and probing the co-evolution of galaxies and their supermassive black holes across cosmic time. These goals are all central to the broader scientific themes of the survey. The

**NASA Establishes New Class
of Astrophysics Missions,
Selects Studies**

Astro2020 Decadal Survey Section 7.5.3.3 :

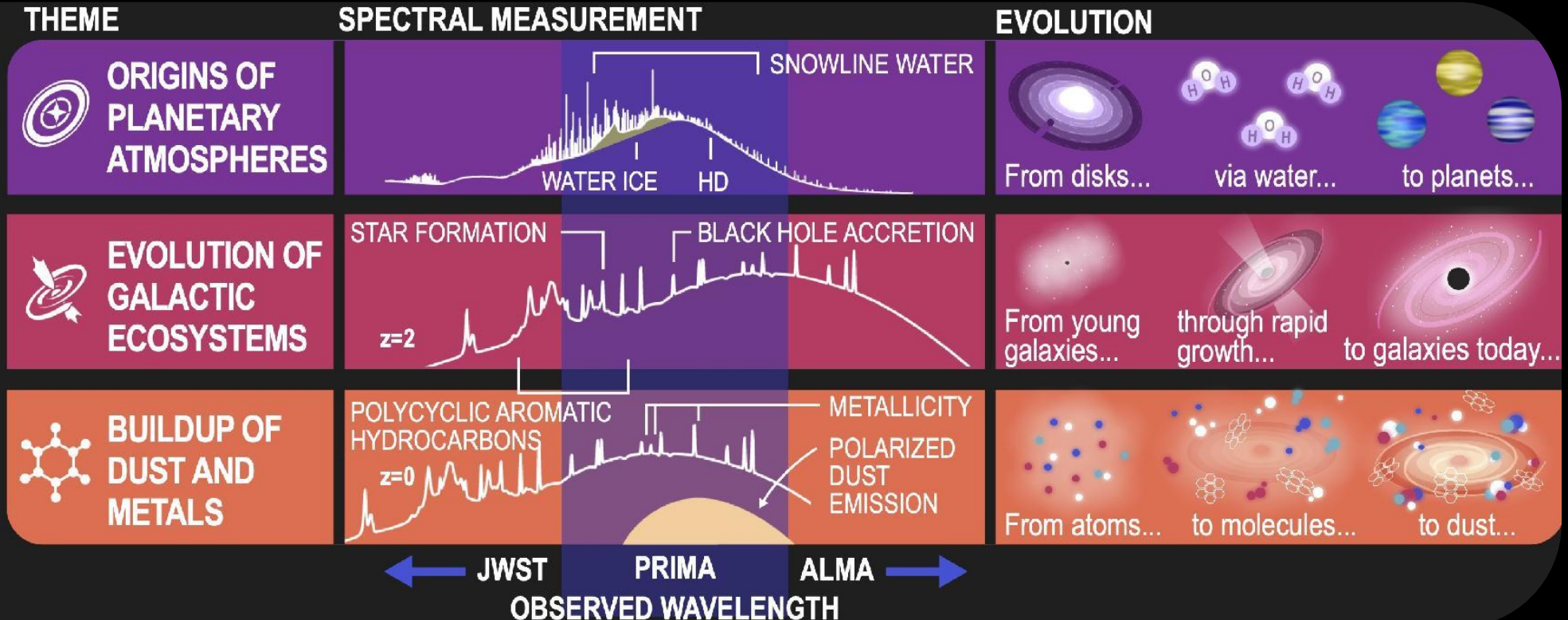


and a probe scale mission is an extremely timely and compelling opportunity to do so. These scientific areas include tracing the astrochemical signatures of planet formation (within and outside of our own Solar System), measuring the formation and buildup of galaxies, heavy elements, and interstellar dust from the first galaxies to today, and probing the co-evolution of galaxies and their supermassive black holes across cosmic time. These goals are all central to the broader scientific themes of the survey. The

NASA Establishes New Class of Astrophysics Missions,



PRIMA uses the power of the far-infrared to see into the hearts of dusty and obscured sources across cosmic time.



PRIMA team

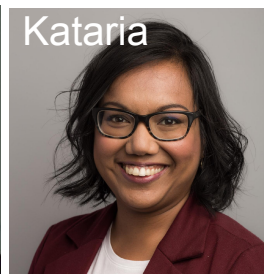
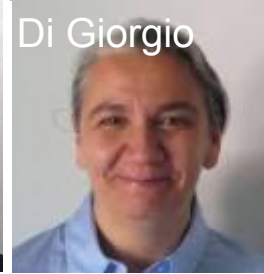
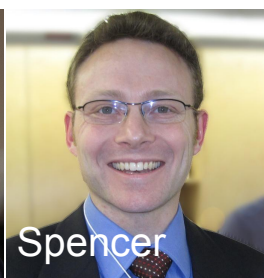
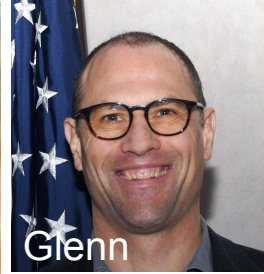
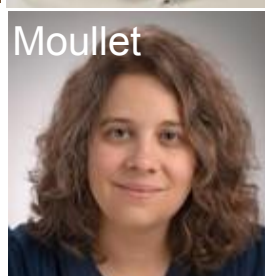
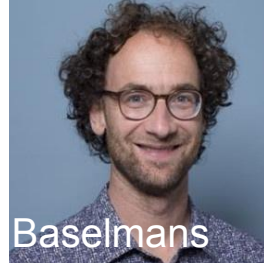
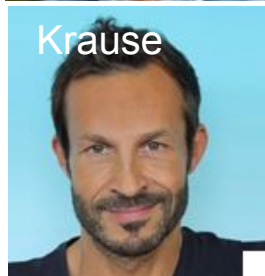
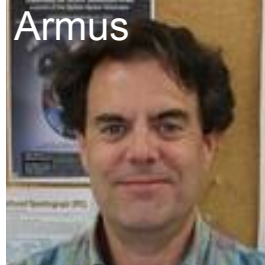
*An international team
of astro/ technology
experts*

Co-I's shown, plus a
strong corps of
engineers at JPL, GSFC,
& BAE Systems

Partner Institutions

JPL • GSFC • BAE
Systems • ASI / INAF •
IPAC • CNES • MPIA •
SRON • CSA • JAXA •
KASA • UKSA

+ science affiliates
+ *many* community science
working group members!!



Jason Glenn, GSFC
Principal Investigator

Margaret Meixner, JPL
Deputy PI

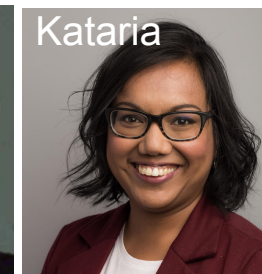
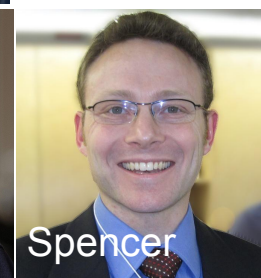
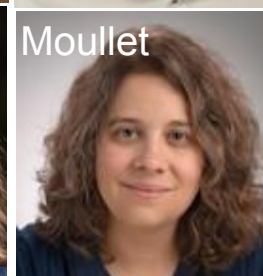
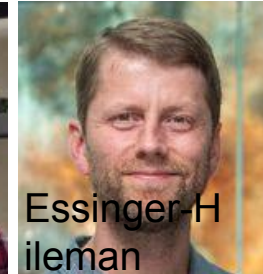
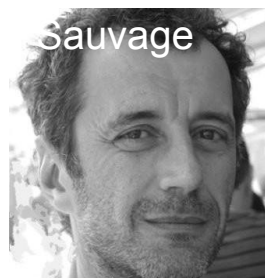
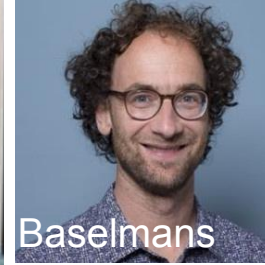
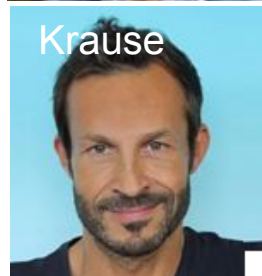
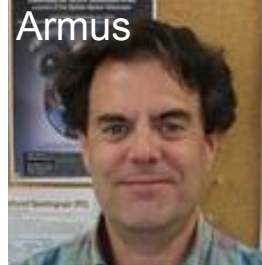
Matt Bradford, JPL
Project Scientist

Klaus Pontoppidan, JPL
Deputy Project Scientist

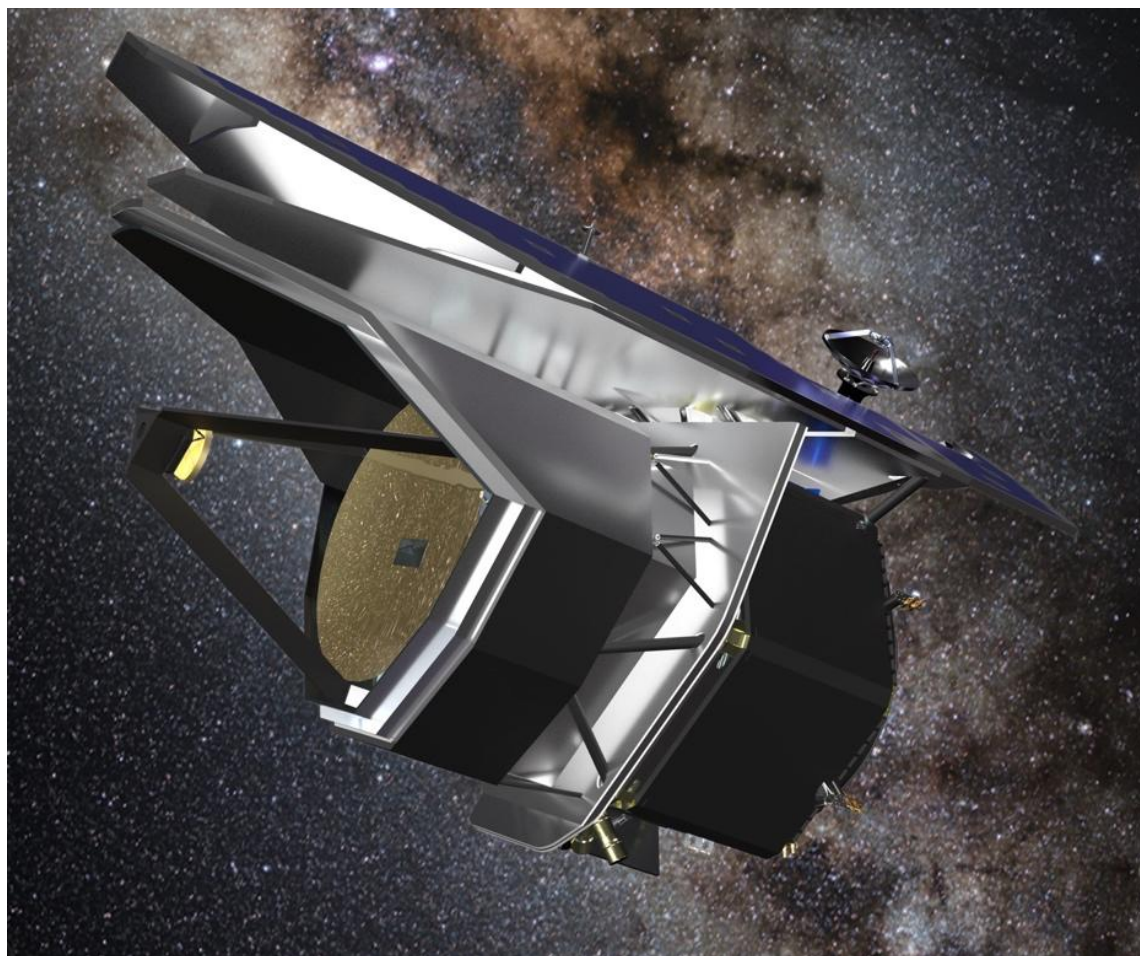
Alexandra Pope, UMass
Science Lead

Tiffany Kataria, JPL
Deputy Science Lead

+ science affiliates
+ *many* community science
working group members!!



PRIMA



Telescope 1.8-m, all aluminum, 4.5 Kelvin

PRIMAger
Imager &
polarimeter

FIRESS
Spectrometer

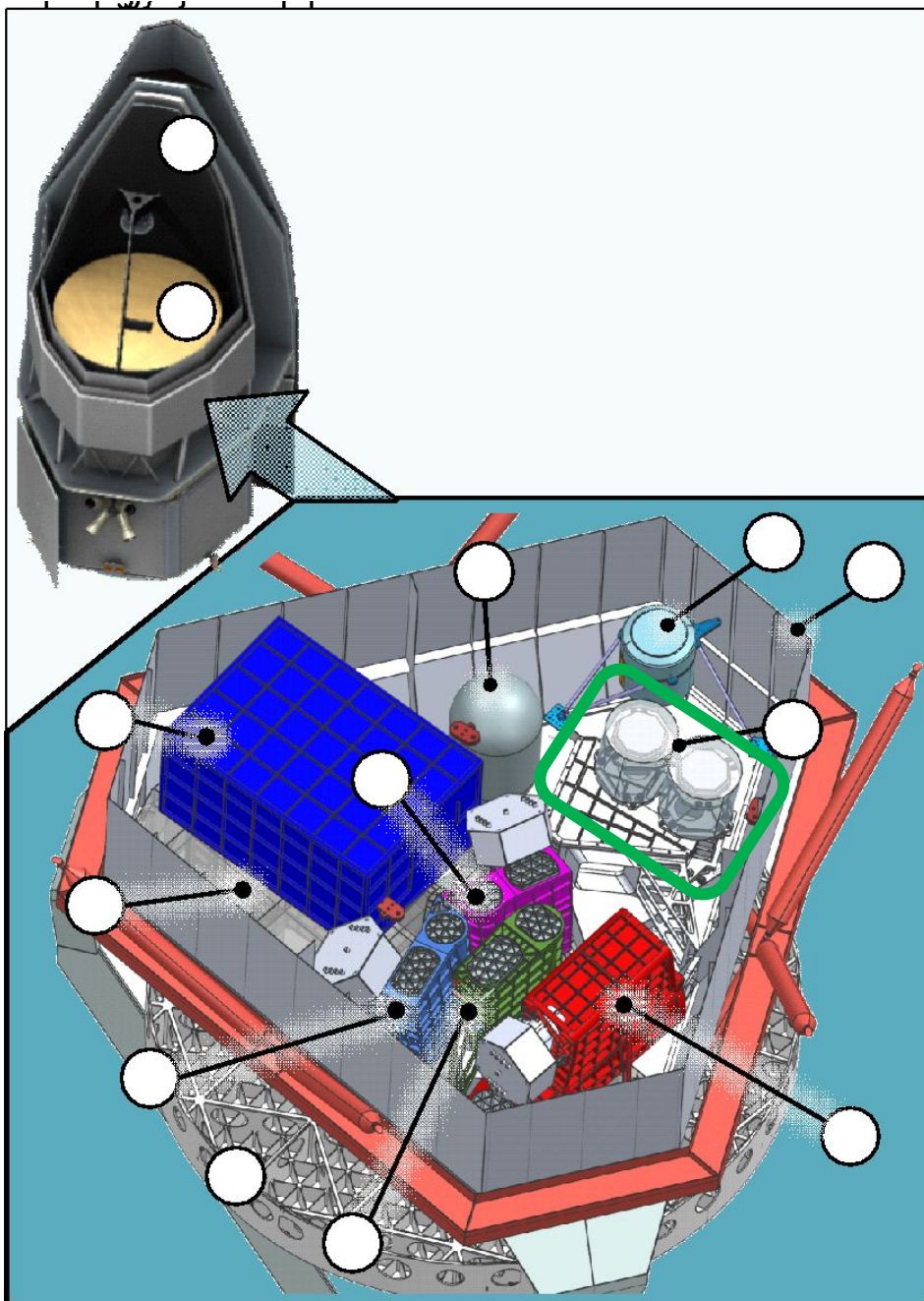
Detectors 100 mK KID arrays (~12k total)

Data IPAC

Orbit Earth-Sun L2

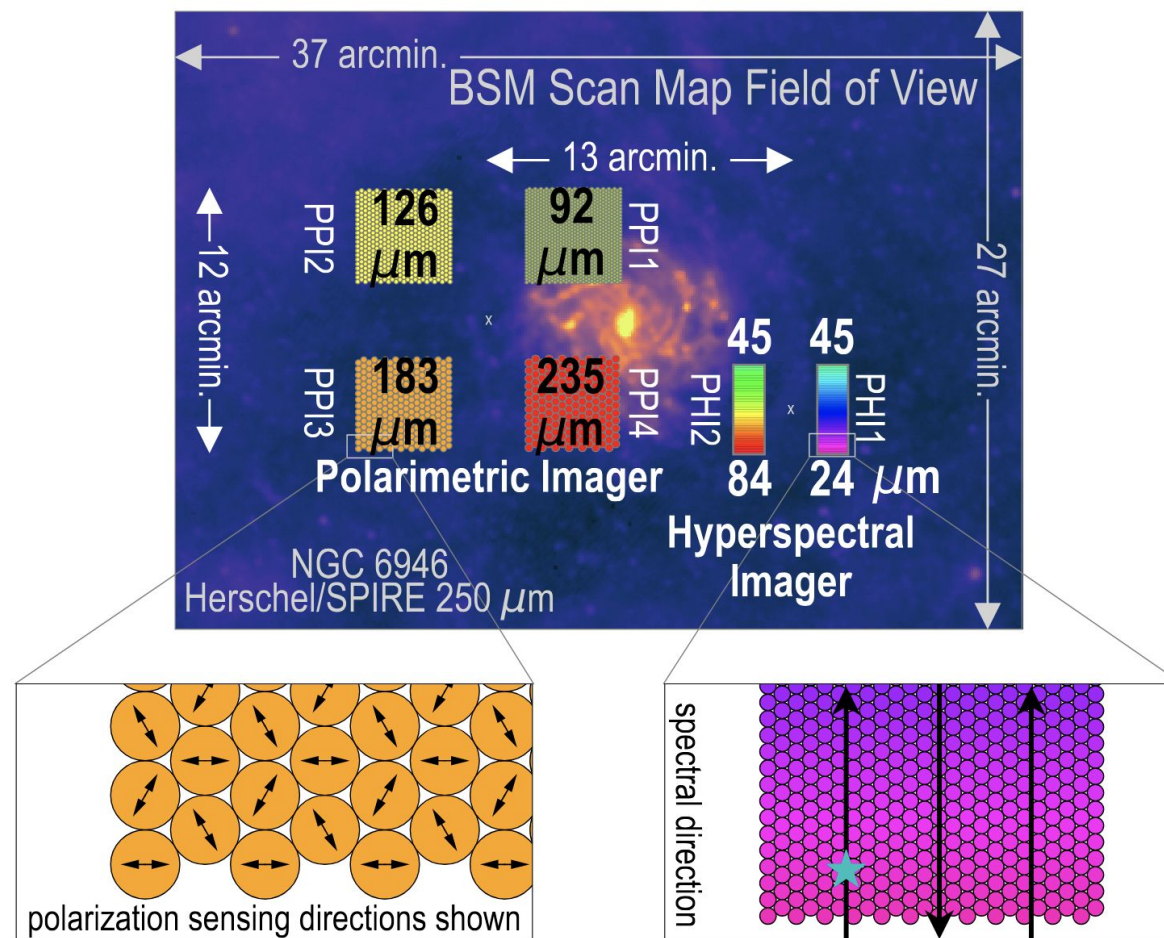
Launch 2032

Observations 75% GO, 25% PI (□ GI)



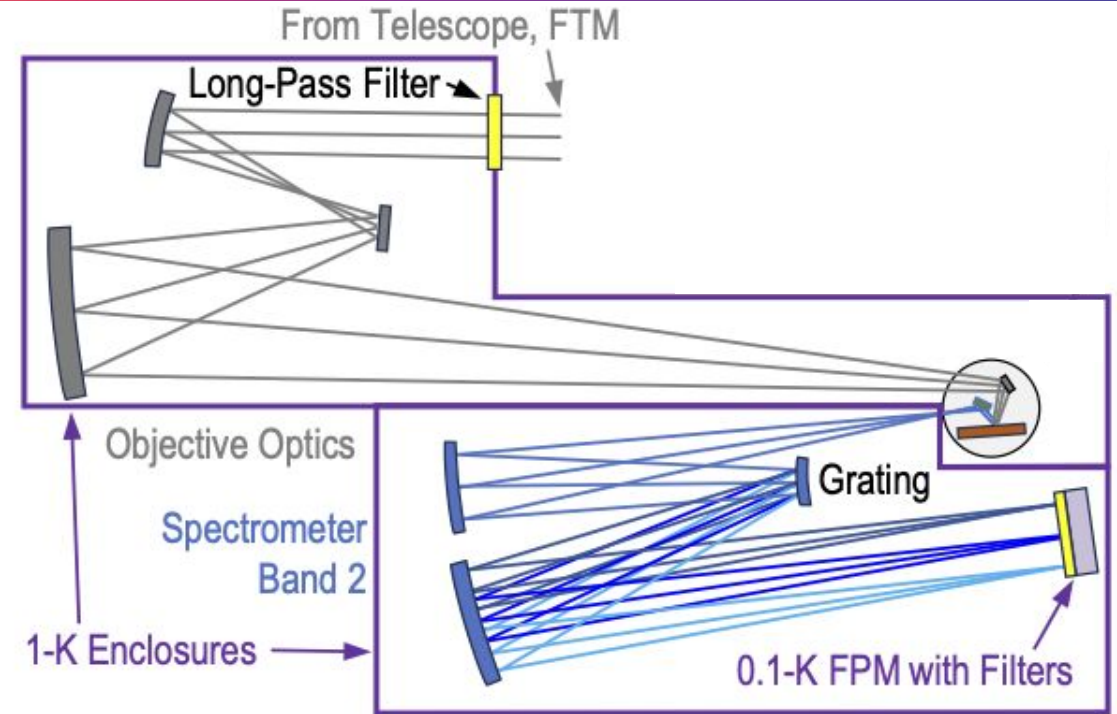
PRIMAgar (French / Dutch contribution)

- Two R>8 Hyperspectral focal planes using linear variable filters (LVFs): (24 – 84 μm , PHI1/PHI2)
- Four R=4 polarimetric imaging arrays: (80 – 264 μm , PPI1-4)
- 3993 total pixels

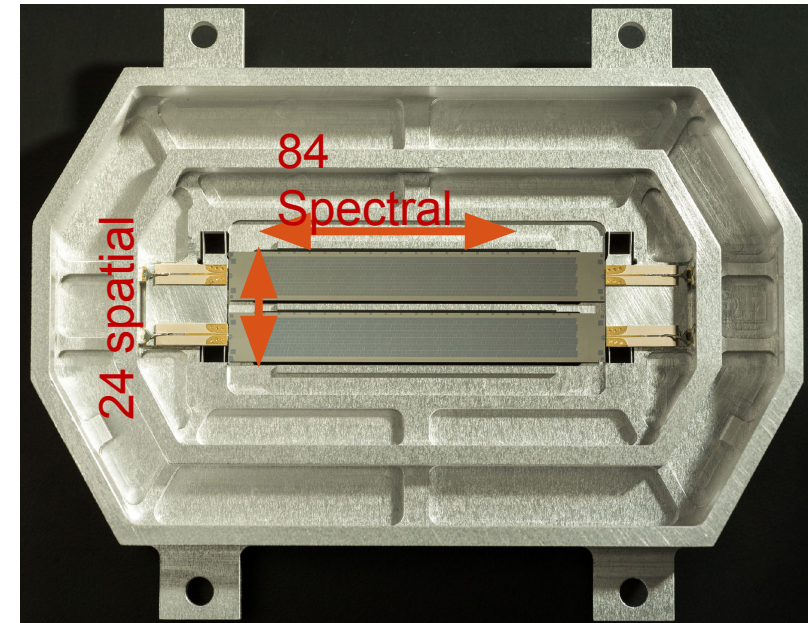


FIRESS (JPL)

- 4 slit-fed grating modules giving $R \sim 100$ from 24-235 μm
- 2 pointings for full spectrum of a source, though all 4 bands read out.
- High-res mode (with Fourier Transform module) providing $R = 4,400 \times (112\mu\text{m}/\lambda)$

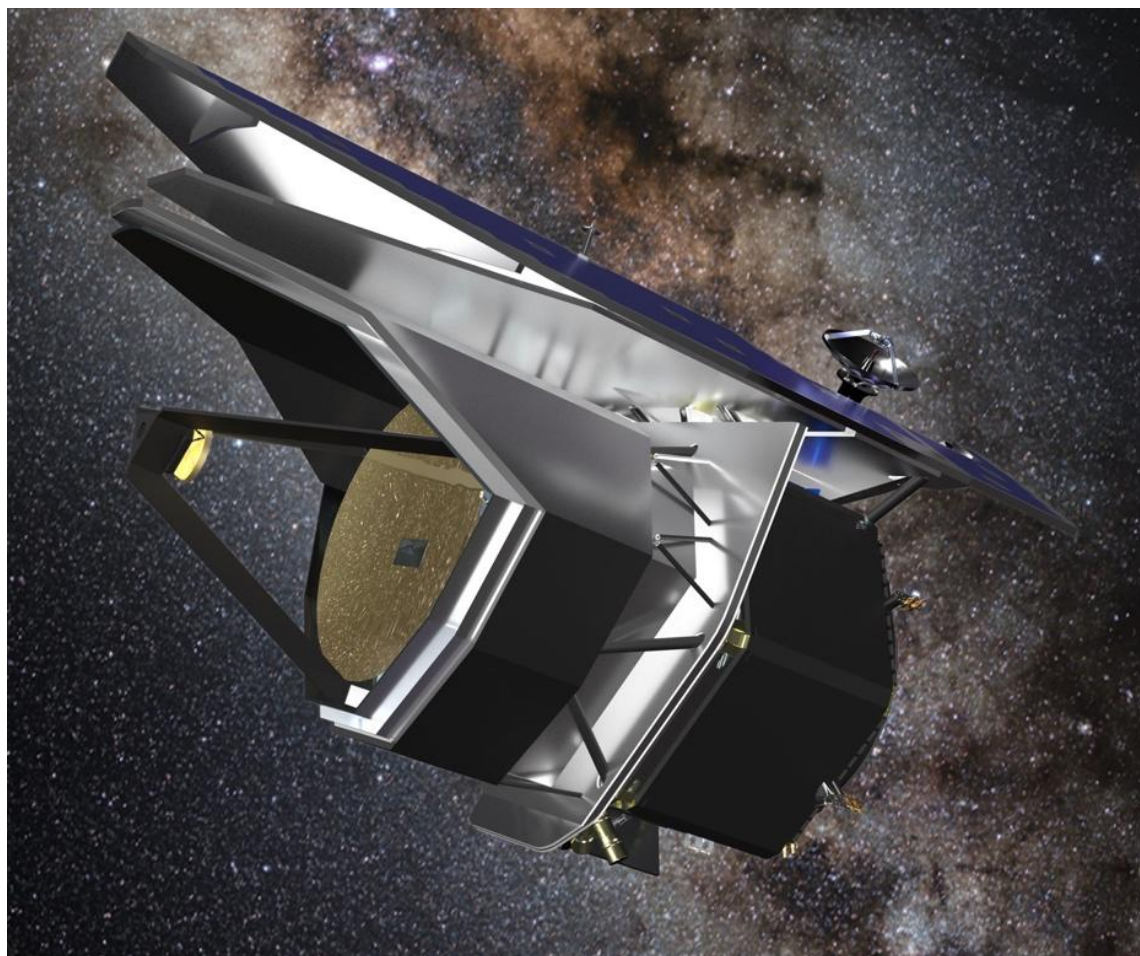


Parameter	Band 1	Band 2	Band 3	Band 4
Spectral range (μm)	24–43	42–76	74–134	130–235
Spectral sampling (μm)	0.23	0.41	0.73	1.29
Resolving power	95-150	85-120	90-125	95-130
Array format per band	24 spatial $\times$ 84 spectral pix, 900- μm pitch			
Pix size on sky (arcsec)	7.6		12.7	22.9
Pix pitch ratio to B1,2	-		5:3	3:1



Prototype array in flight-like package

PRIMA



Telescope 1.8-m, all aluminum, 4.5 Kelvin

PRIMAger
Imager &
polarimeter

FIRESS
Spectrometer

Detectors 100 mK KID arrays (~12k total)

Data IPAC

Orbit Earth-Sun L2

Launch 2032

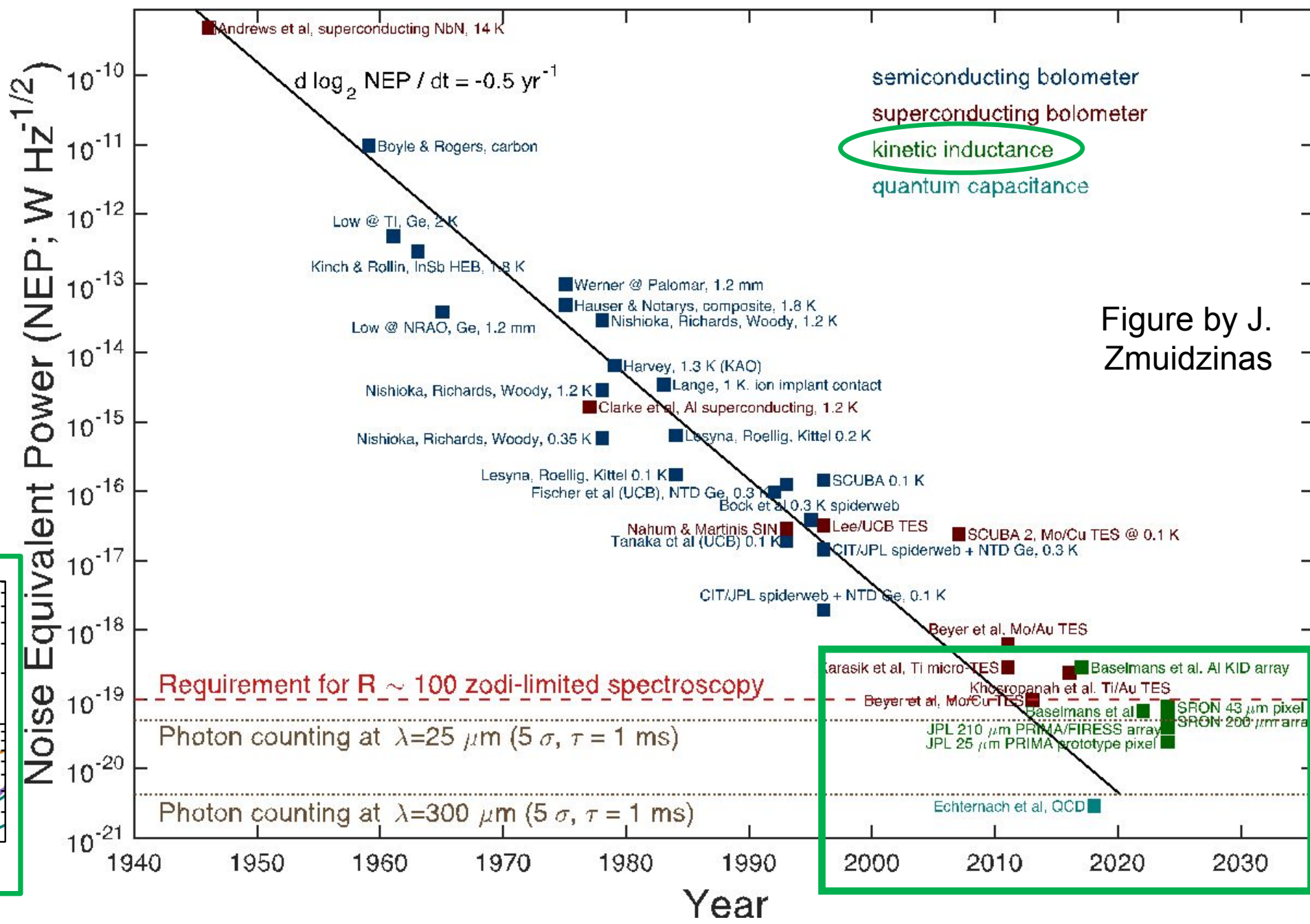
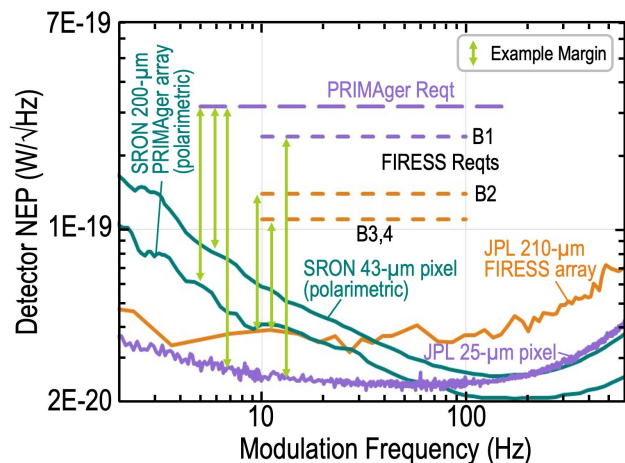
Observations 75% GO, 25% PI (□ GI)

Why Now?

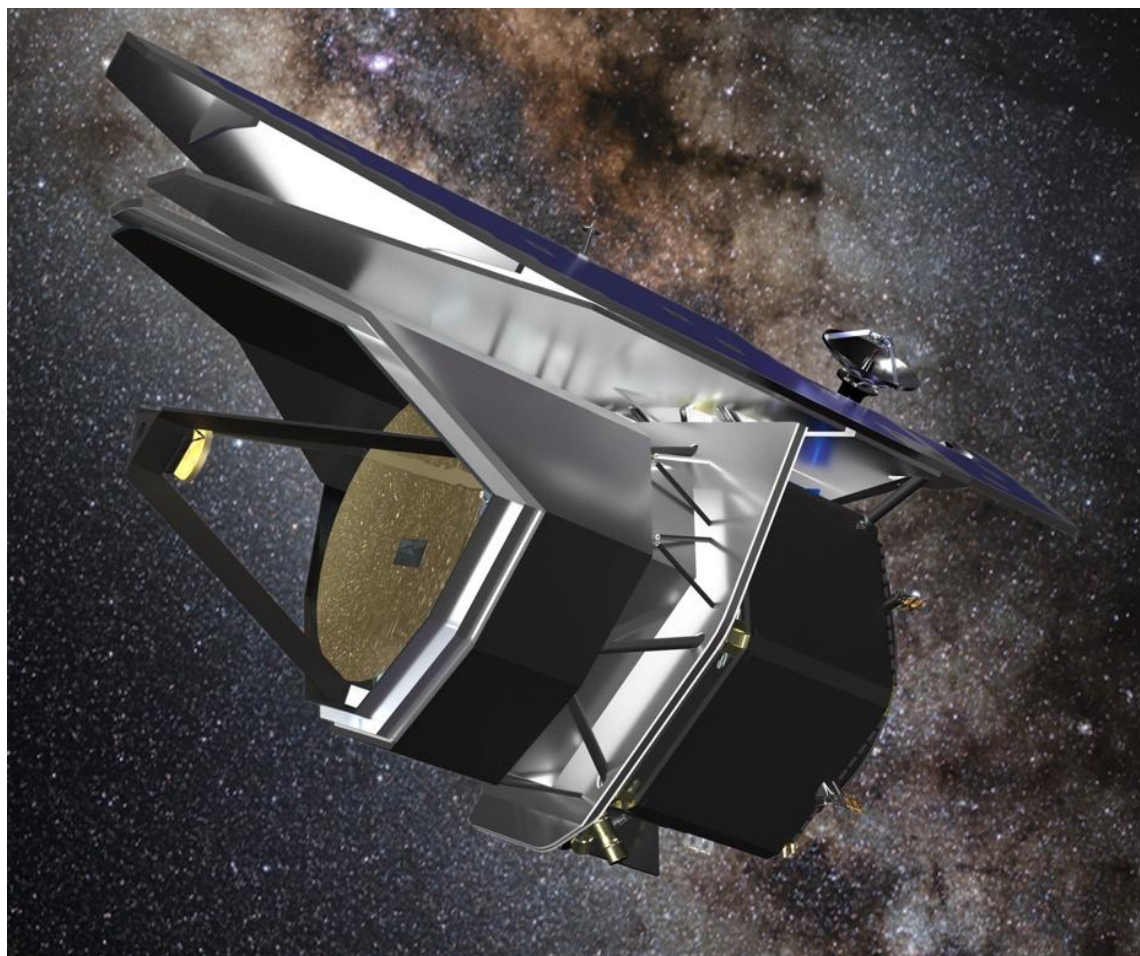
Far-IR Detector Technology

Sensitivities of far-IR detectors have doubled every ~2 years for 75 years!

PRIMA detectors exceed performance requirements over the full wavelength range.



PRIMA



Telescope 1.8-m, all aluminum, 4.5 Kelvin

PRIMAger
Imager &
polarimeter

FIRESS
Spectrometer

Detectors 100 mK KID arrays (~12k total)

Data IPAC

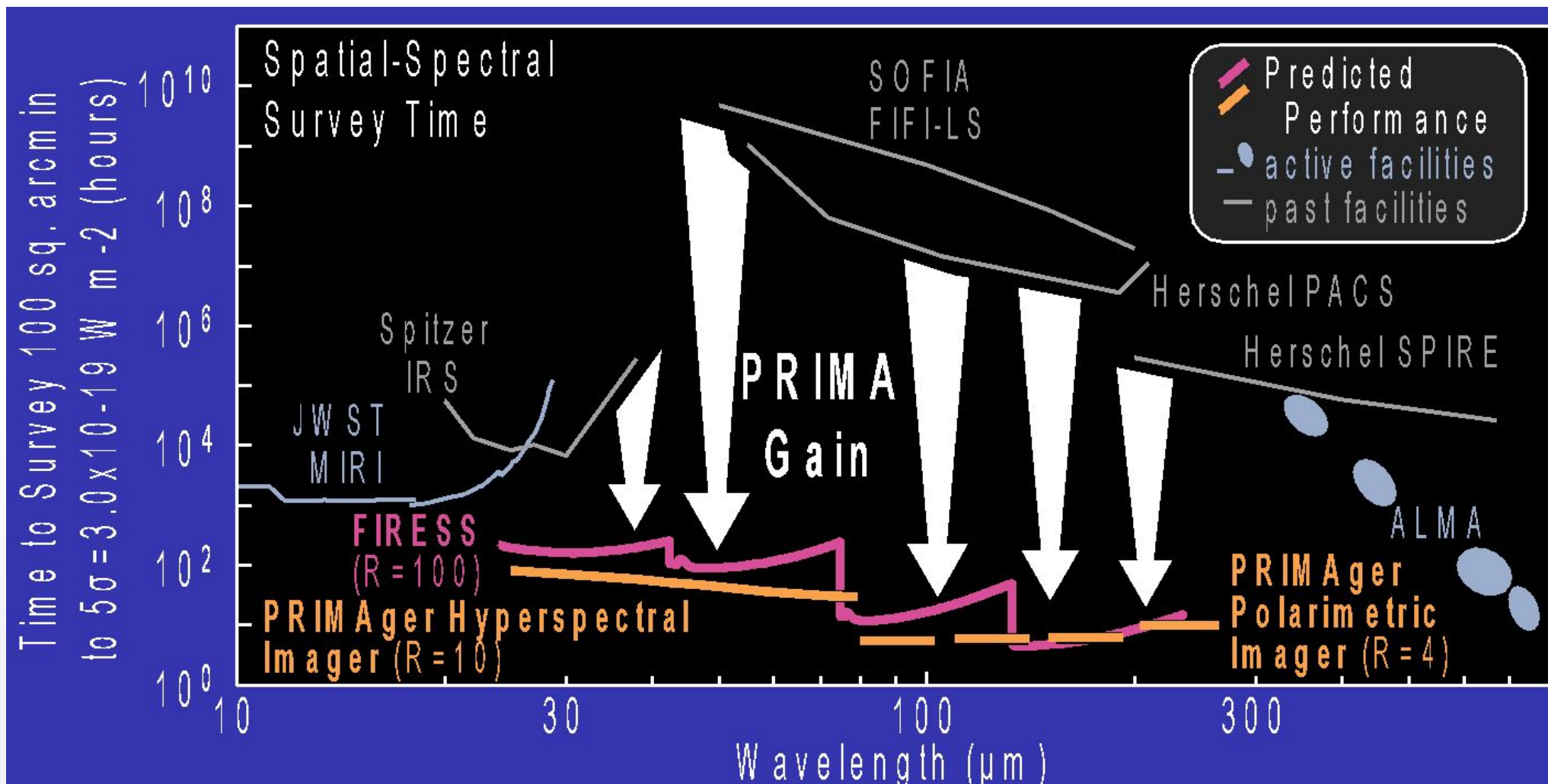
Orbit Earth-Sun L2

Launch 2032

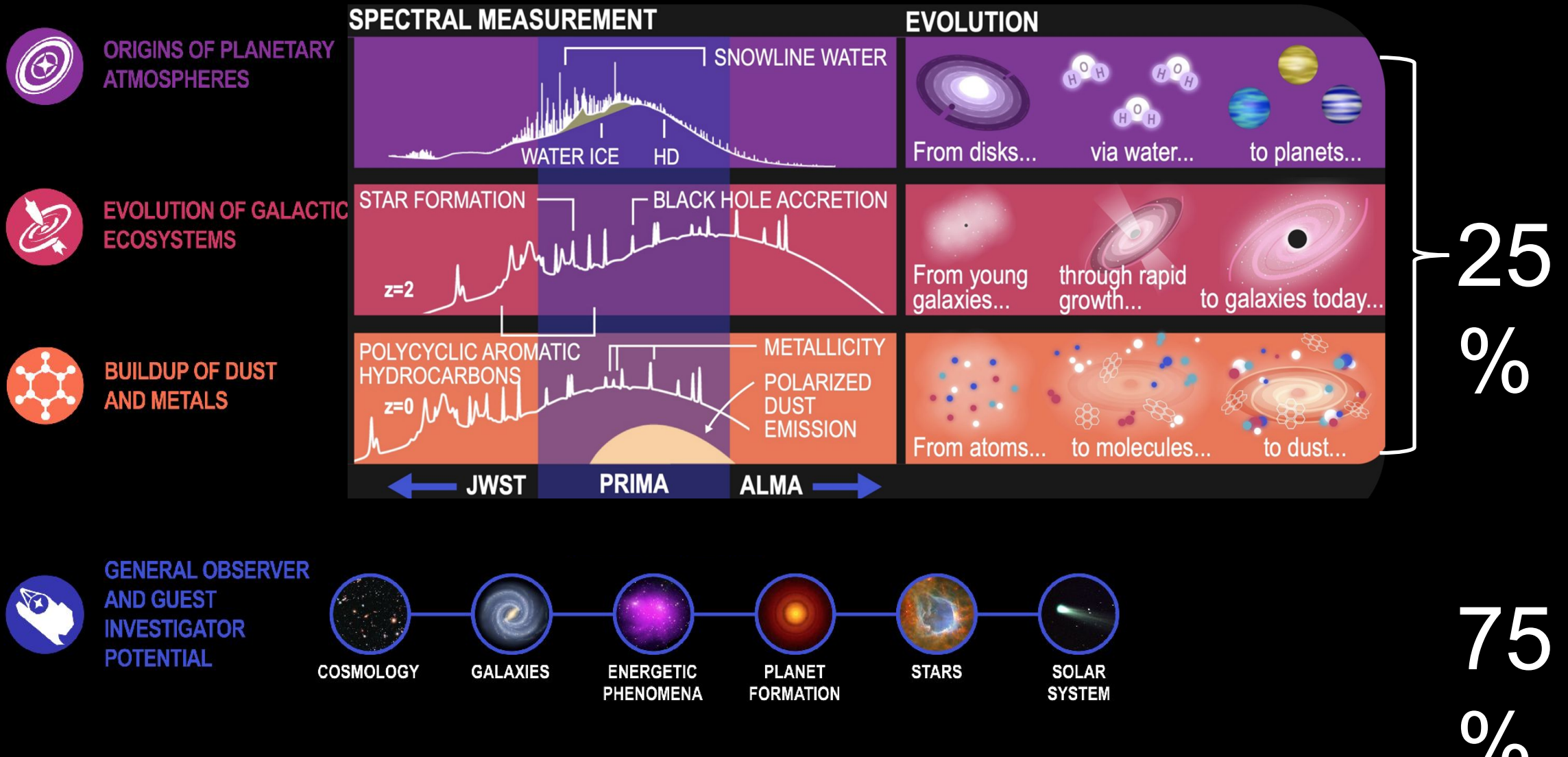
Observation 75% GO, 25% PI (□ GI)

s

PRIMA makes massive gains in sensitivity

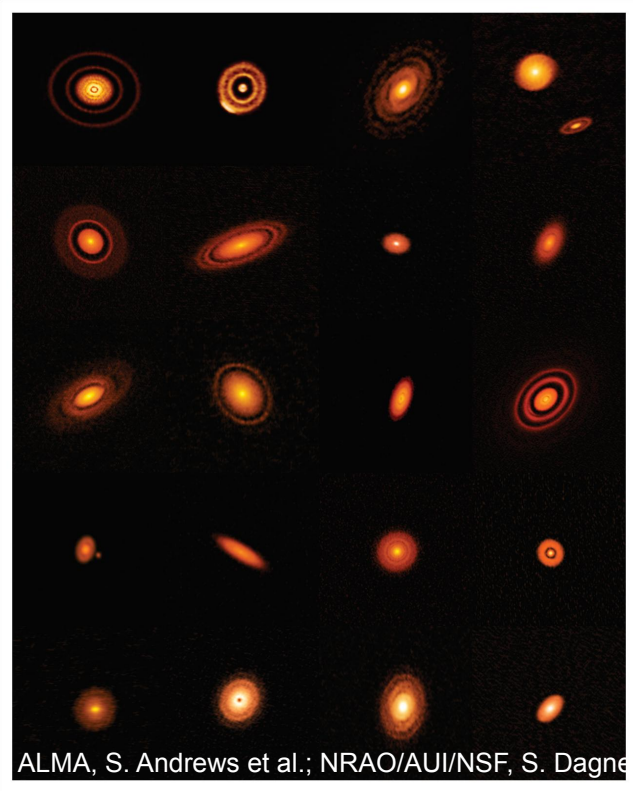


PRIMA addresses Astro2020's 3 science goals for a far-IR probe and opens vast discovery space for the community

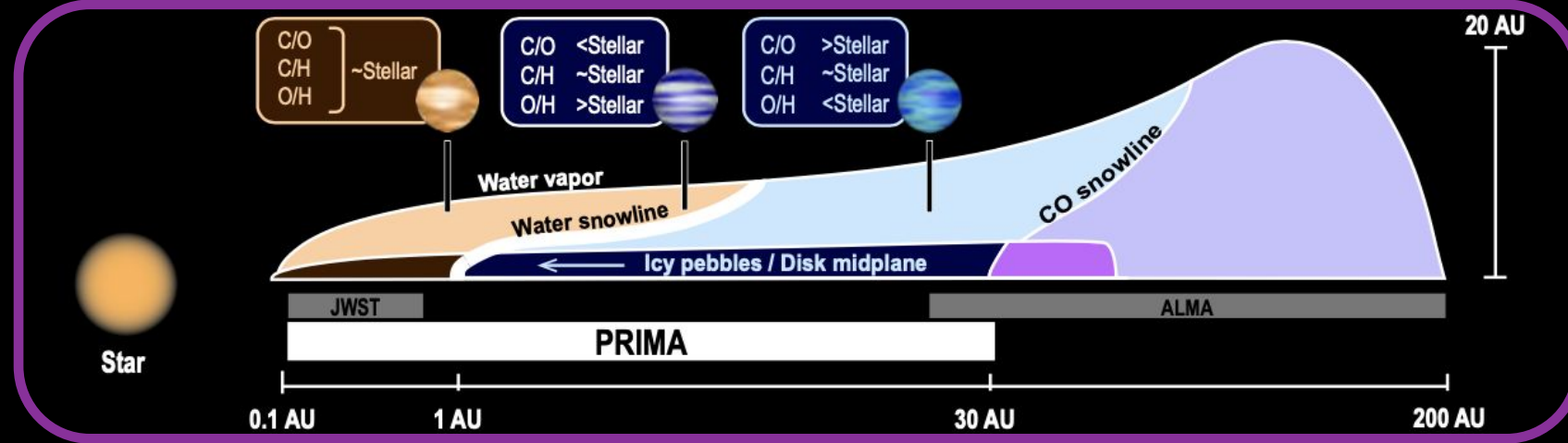


ORIGINS OF PLANETARY ATMOSPHERES

Protoplanetary disk structure is linked to the formation of exoplanets

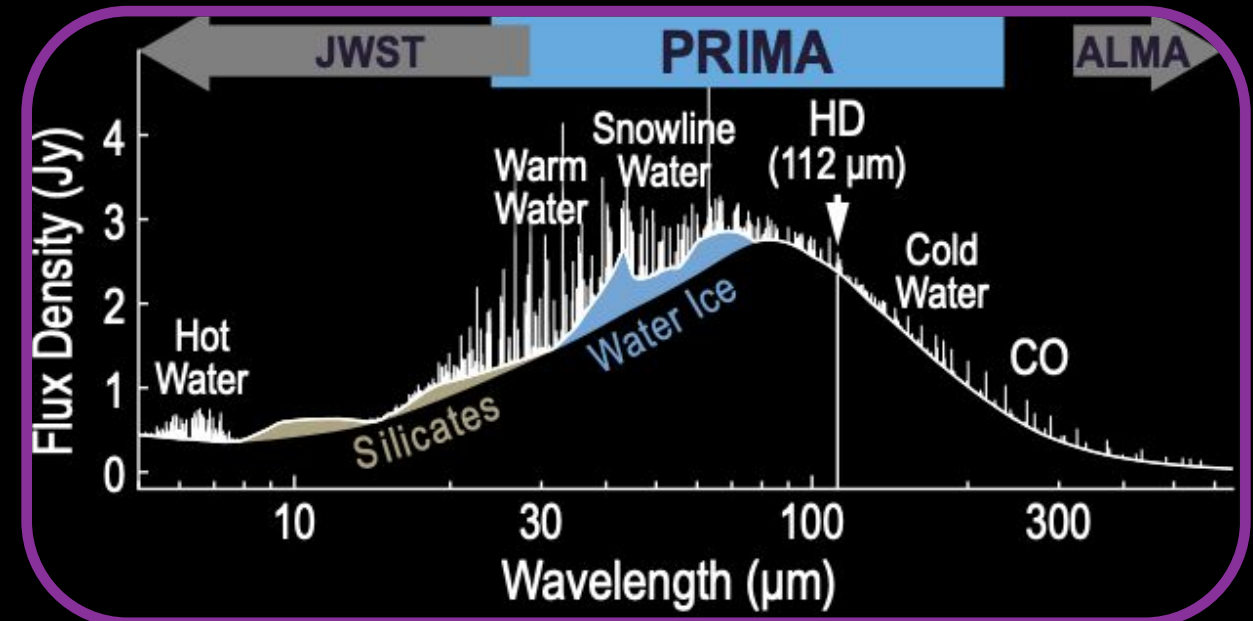


ALMA, S. Andrews et al.; NRAO/AUI/NSF, S. Dagnello

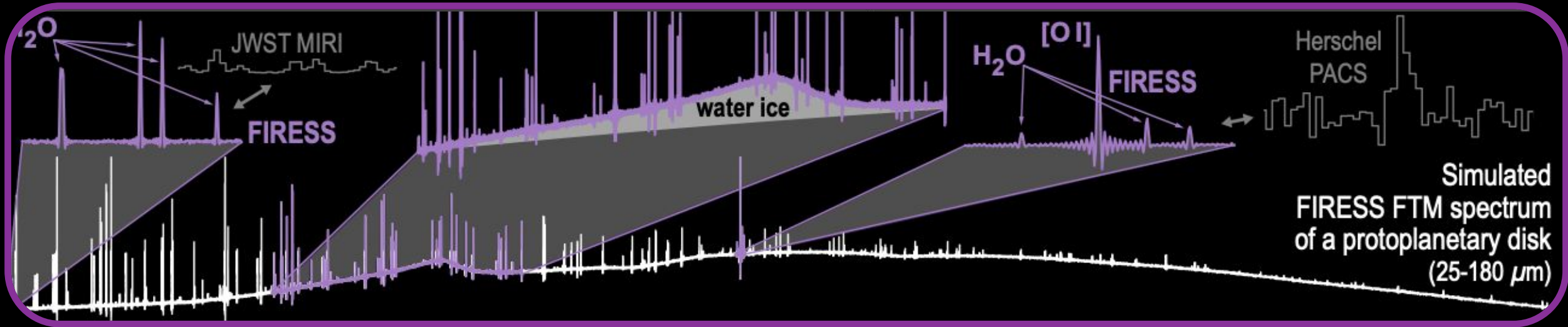


Unknowns and uncertainties

- Disk masses
- Elemental abundances
- Water vapor content and distribution

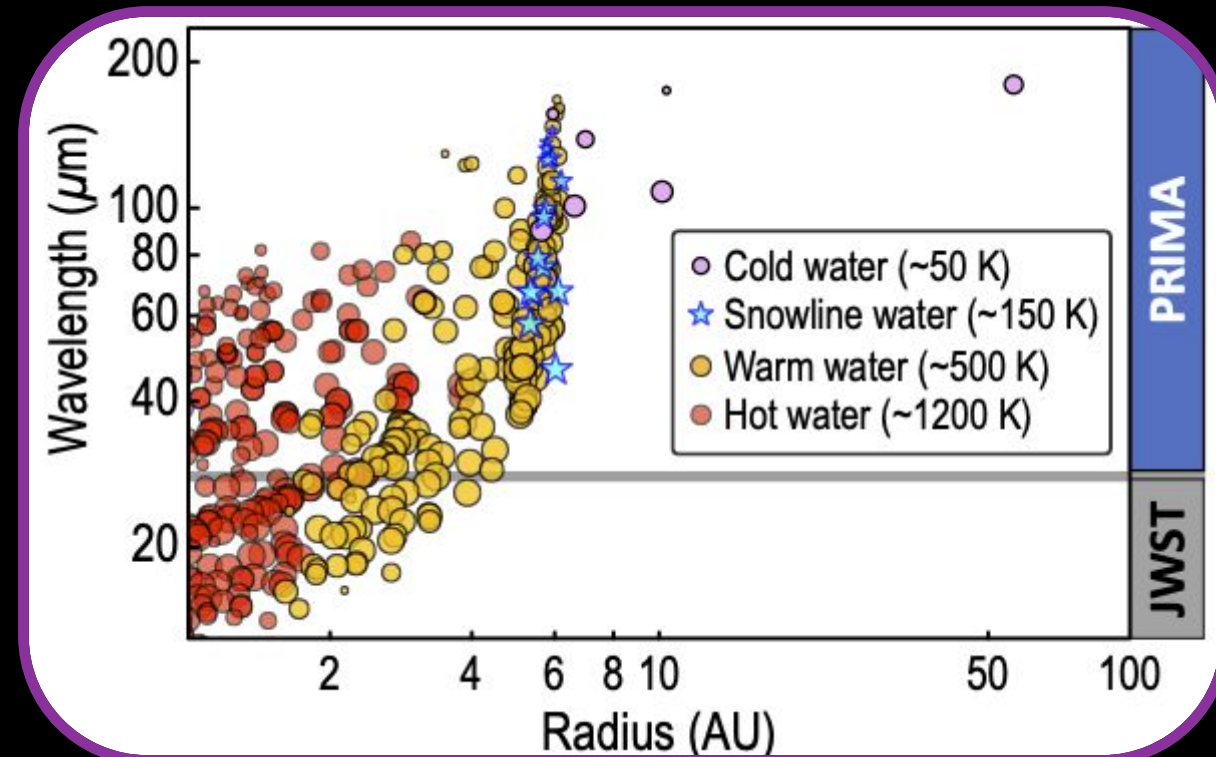
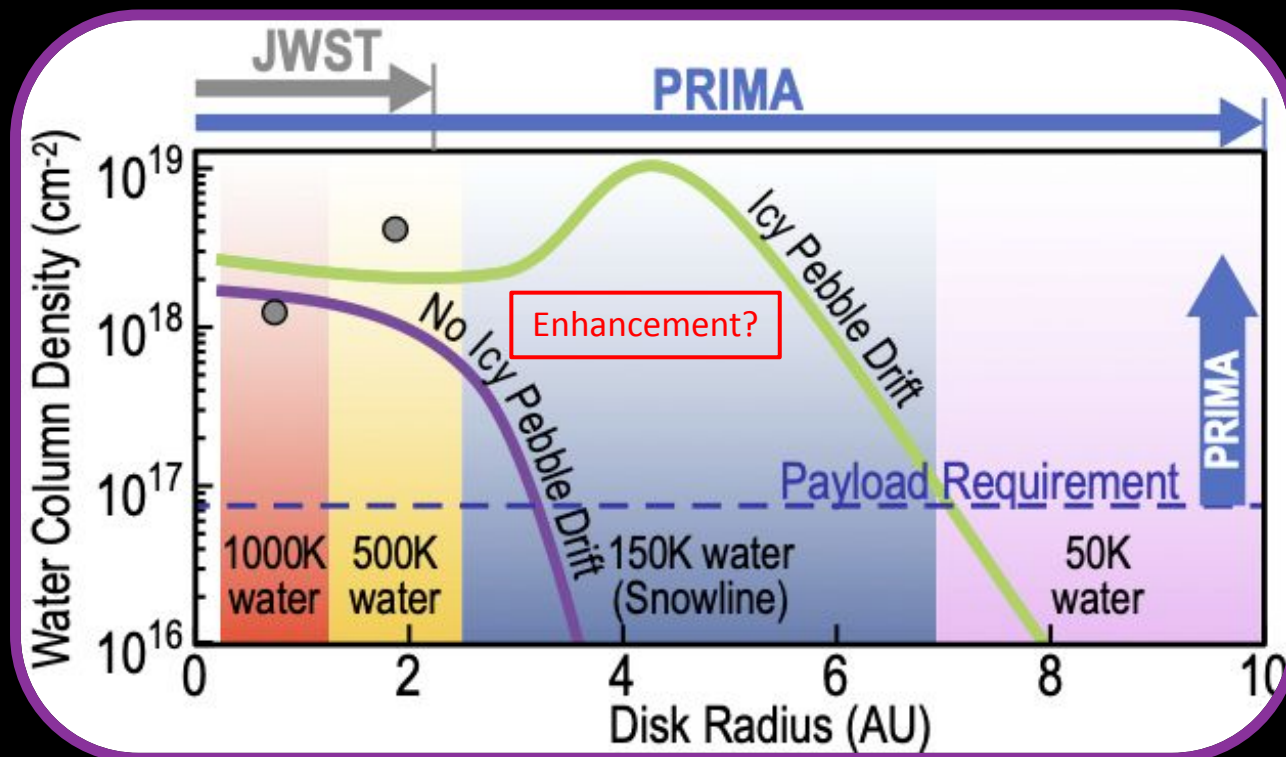


PRIMA will measure the HD mass and water content in 200
protoplanetary disks with high-resolution spectra

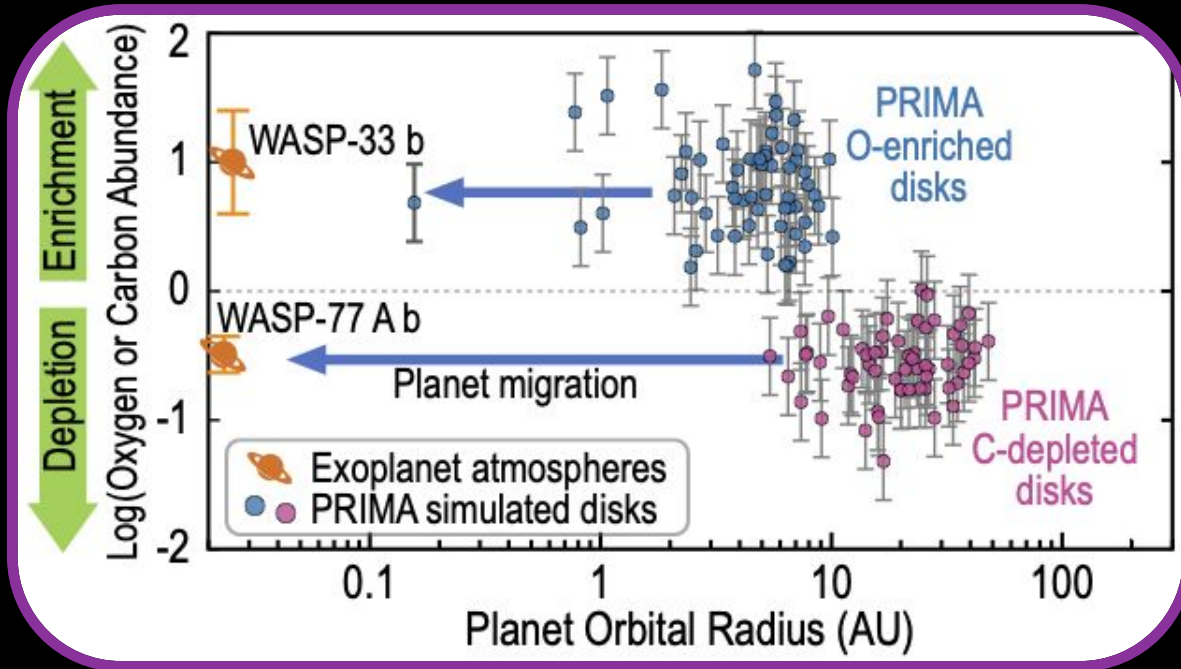


Protoplanetary Disks: Is there enough water mass to drive the formation of planetesimals near the water snowline?

PRIMA/FIRESS FTM will measure the water column density to distinguish models with and without icy pebble drift by observing a wide range of water transitions to study spectral line energy distributions in 200 disks



Linking exoplanet atmospheric abundances to their disk origins: Do protoplanetary disks, at radii where most planets form, have non-solar carbon and oxygen abundances?



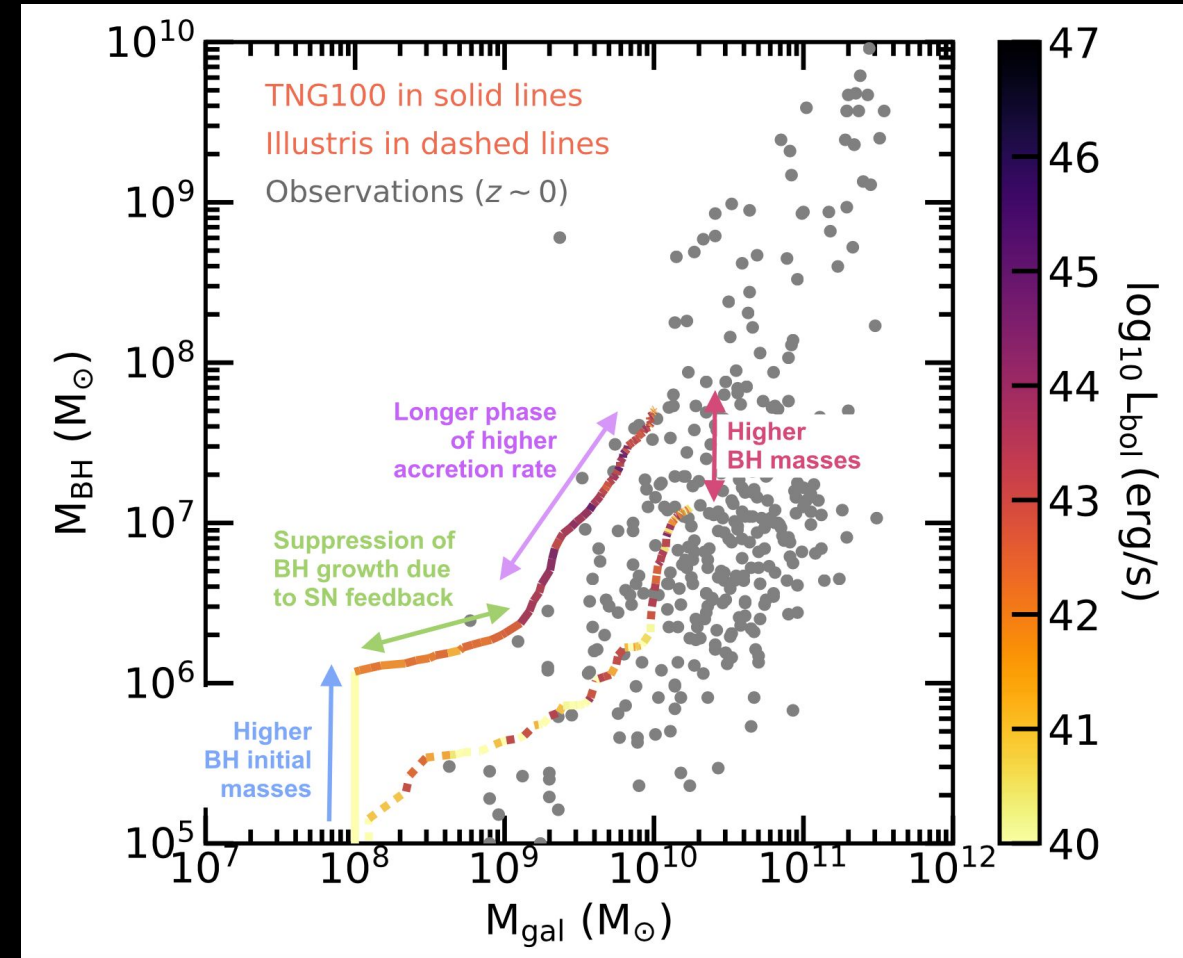
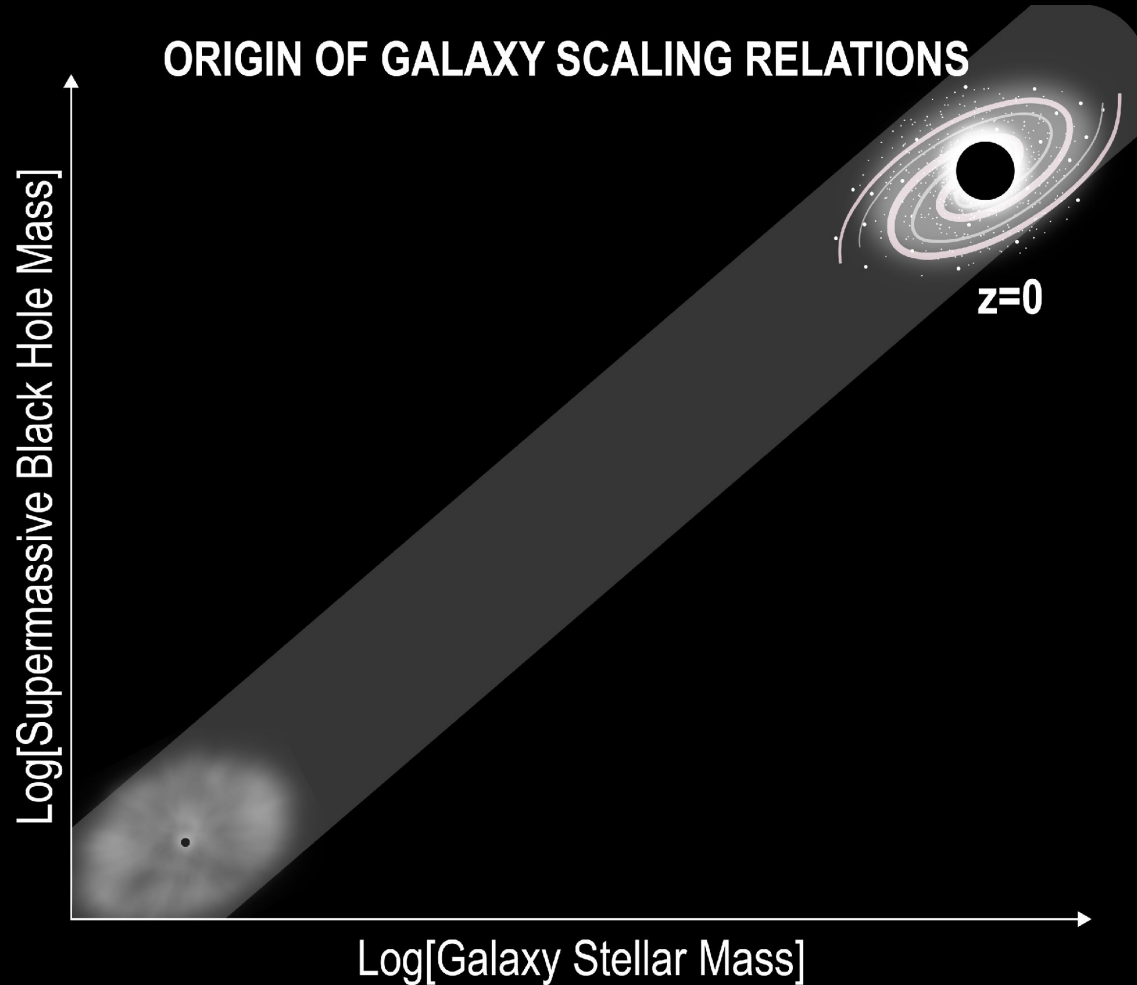
- H_2 mass derived from HD ($112\ \mu\text{m}$), temperatures from existing ALMA CO or CI
- Oxygen derived from water (PRIMA) and carbon from existing CO ALMA observations
- 200 disks of various ages

PRIMA's disk survey simulated as two sub-samples with expected error bars.



EVOLUTION OF GALACTIC ECOSYSTEMS

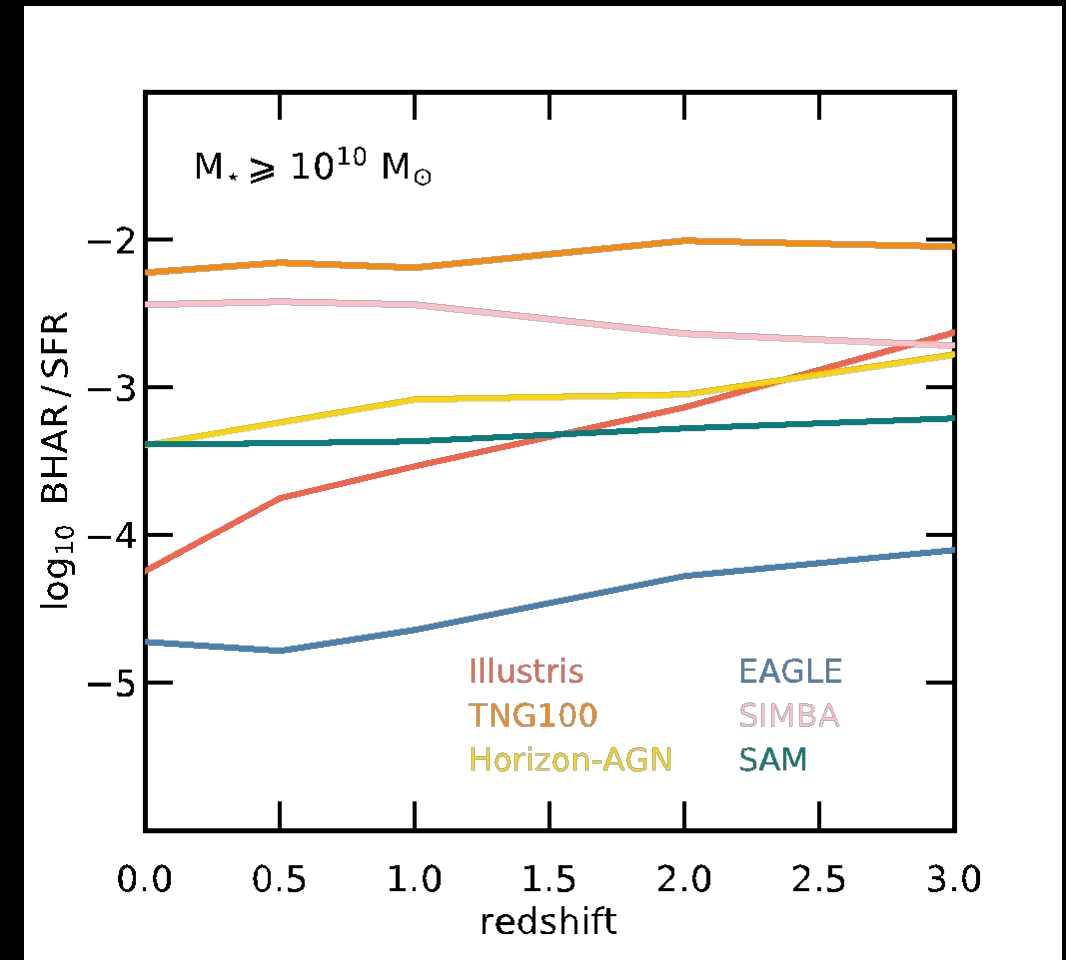
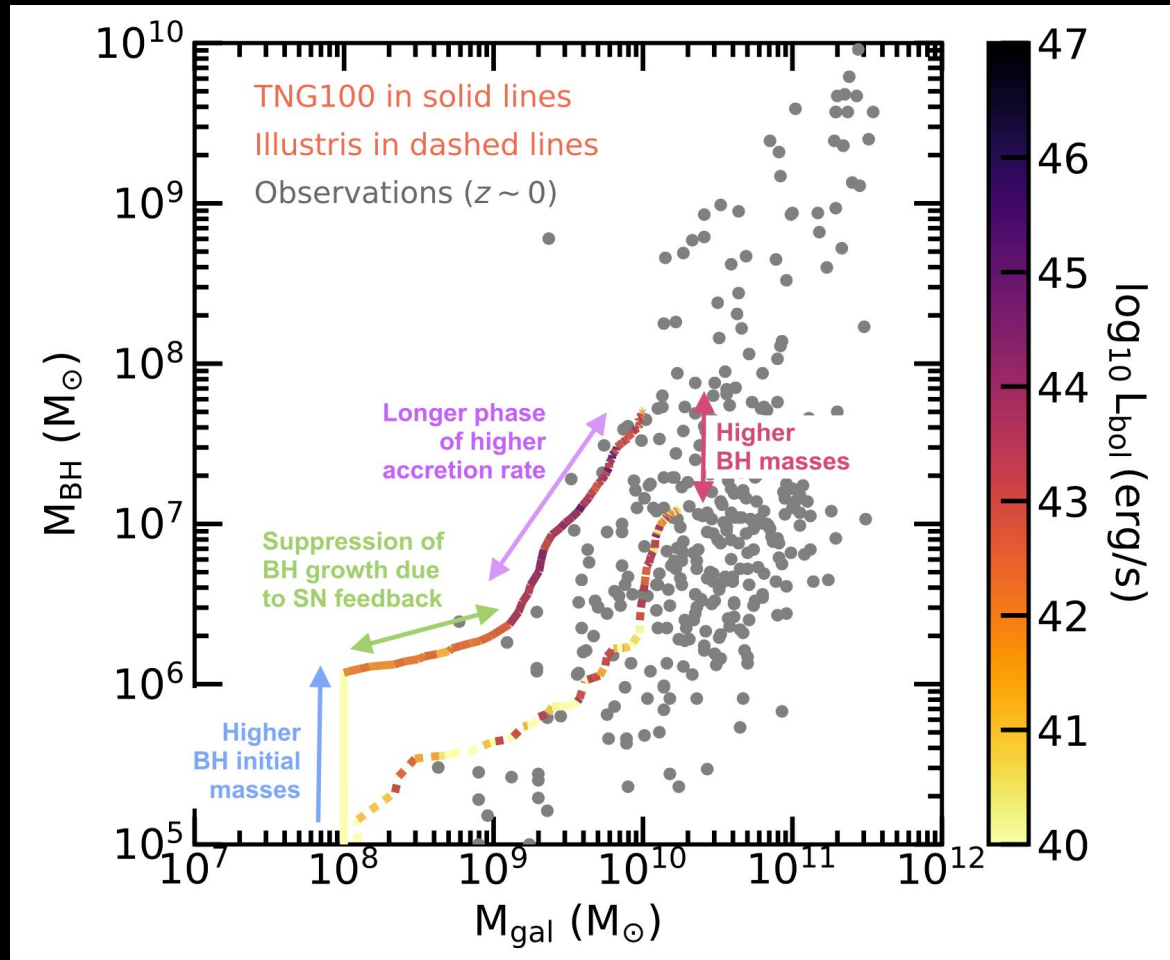
How do supermassive black holes and their host galaxies coevolve?





EVOLUTION OF GALACTIC ECOSYSTEMS

Simulations predict very different pathways for galaxies to arrive on the local $M_{\text{star}}-M_{\text{BH}}$ relation

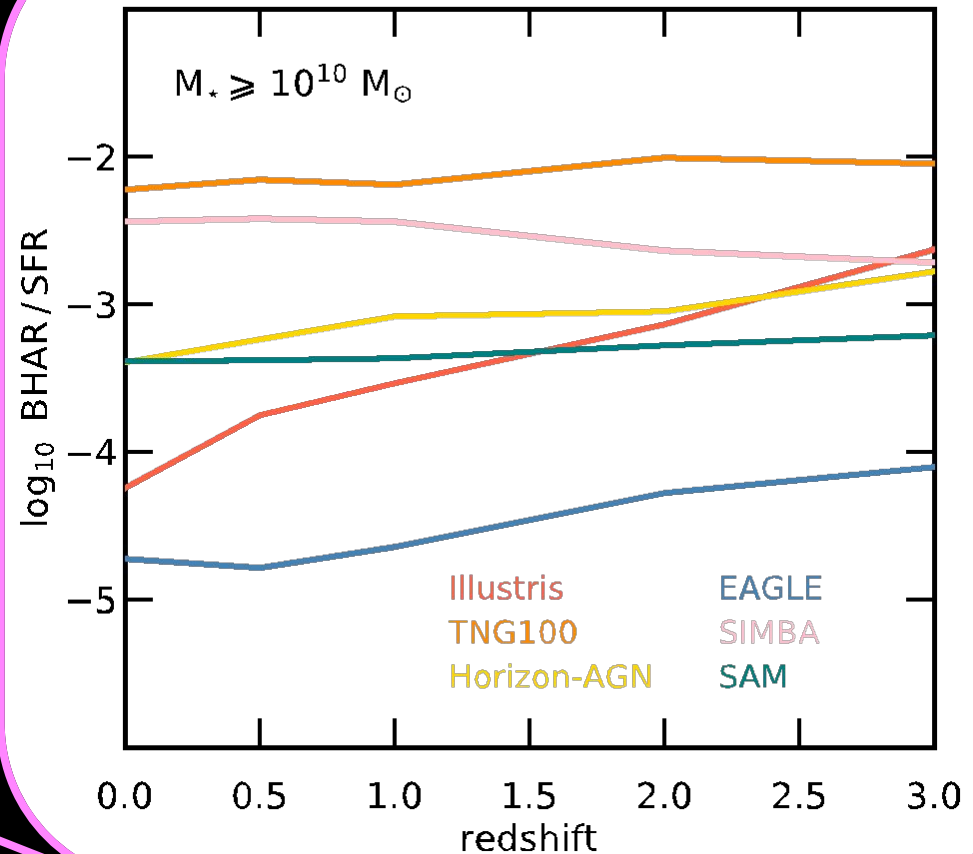




EVOLUTION OF GALACTIC ECOSYSTEMS

Simulations predict very different pathways for galaxies to arrive on the local $M_{\text{star}}-M_{\text{BH}}$ relation

This is what we want to measure: observations of BHAR and SFRs in mass-selected samples as a function of redshift



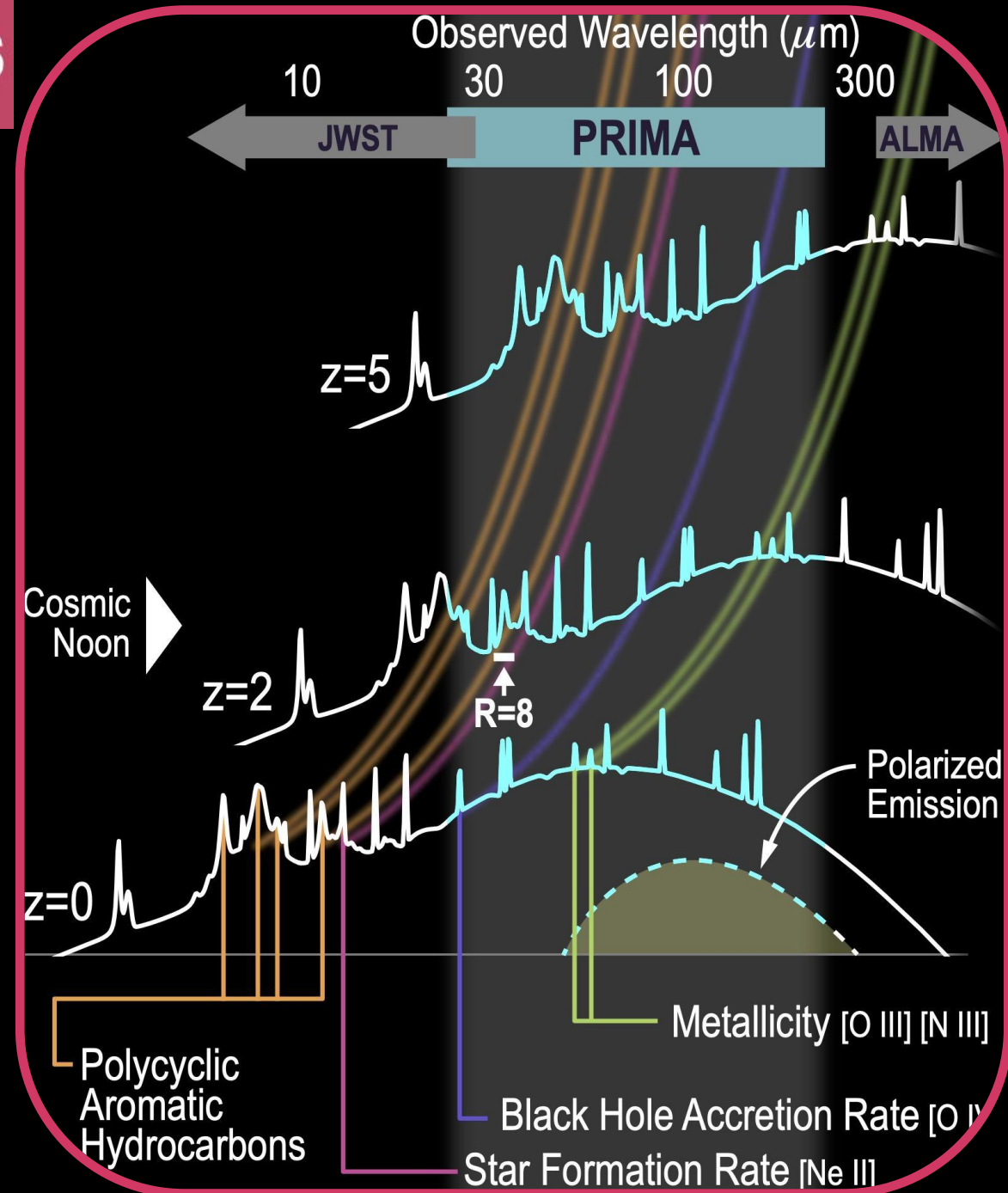


EVOLUTION OF GALACTIC ECOSYSTEMS

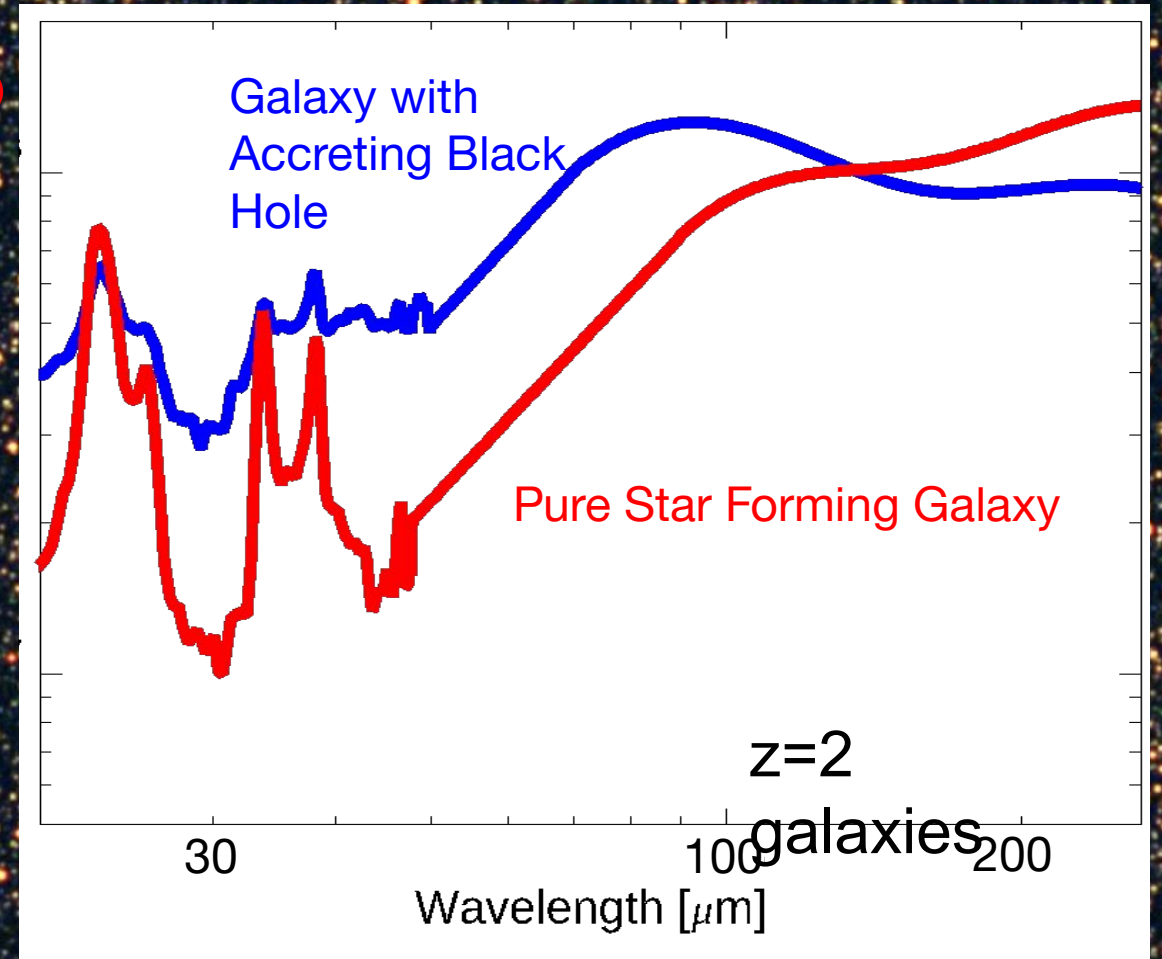
Mid-infrared spectra provide unique signatures of:

- black hole accretion rate (BHAR)
- star formation rate (SFR)

which shift into the far-IR with redshift



3D Hyperspectral surveys: for every galaxy we get a full IR spectral energy distribution distribution

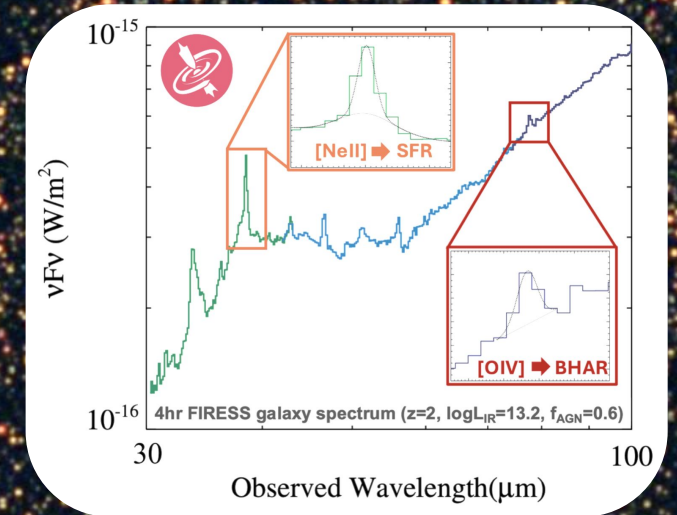
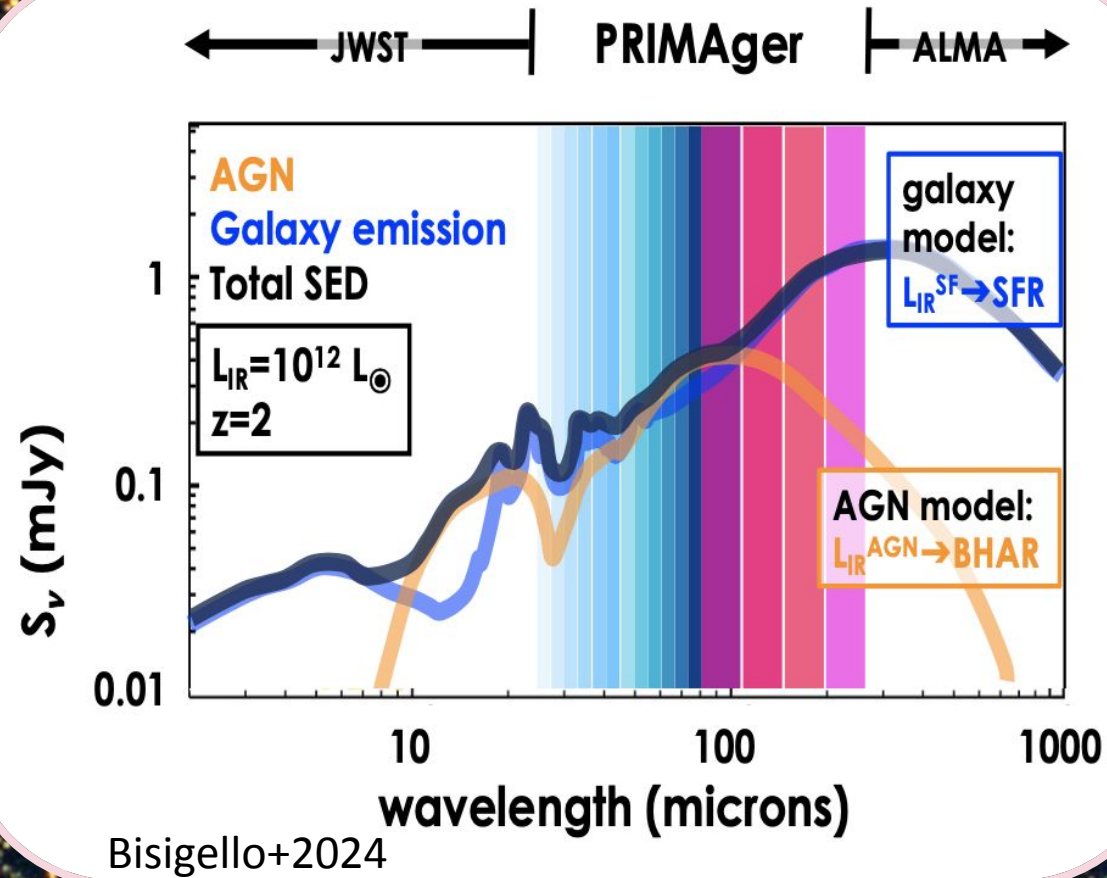


1 deg

Simulated PRIMAgar 3-color image from SIDES

3D Hyperspectral surveys: for every galaxy we get a full IR spectral energy distribution

PRIMAger SED can be decomposed into star formation and AGN components to determine the SFR and the BHAR (verified with FIRESS follow-up of [NeII] and [OIV])



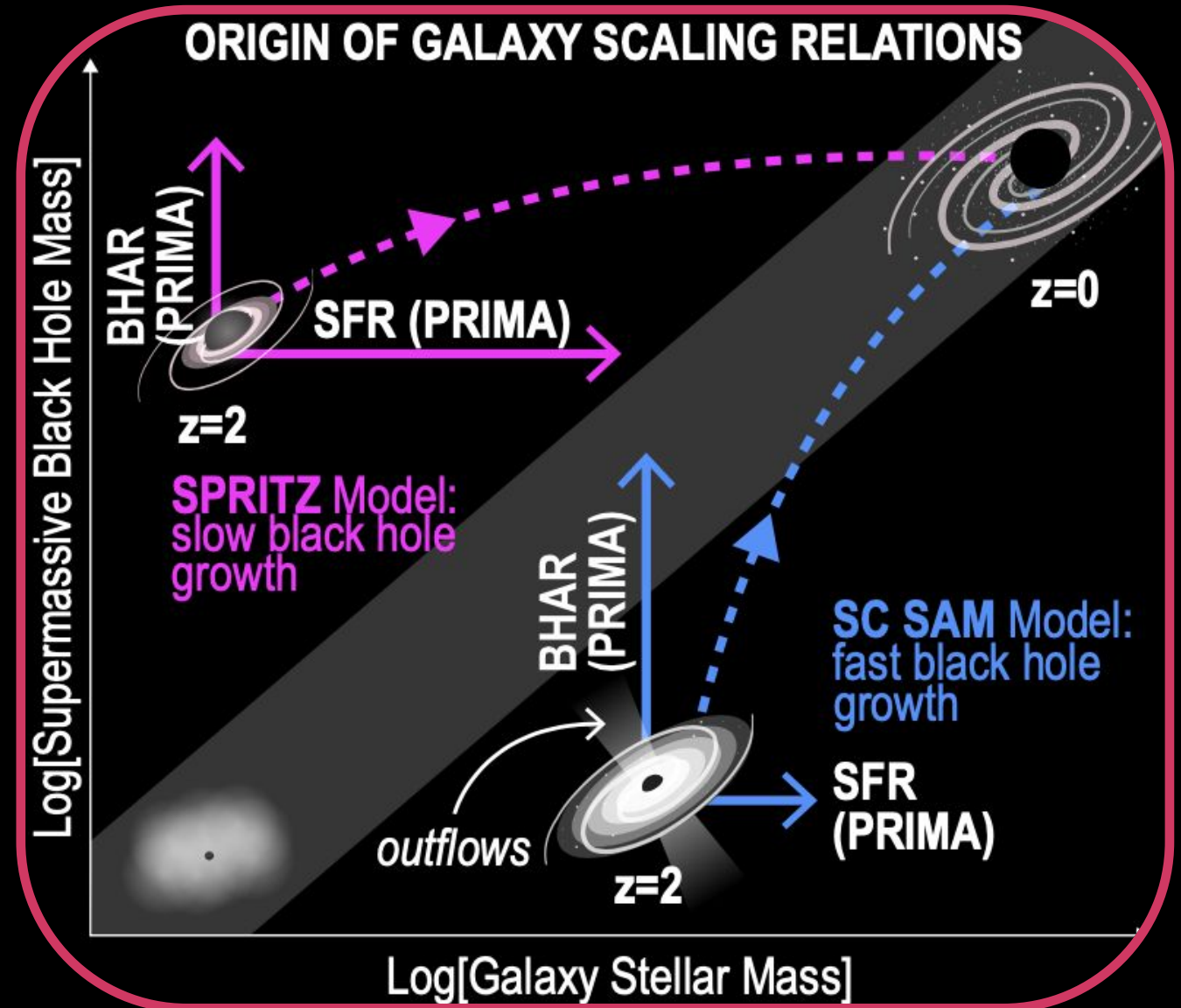
1 deg

Simulated PRIMAger 3-color image from SIDES



EVOLUTION OF GALACTIC ECOSYSTEMS

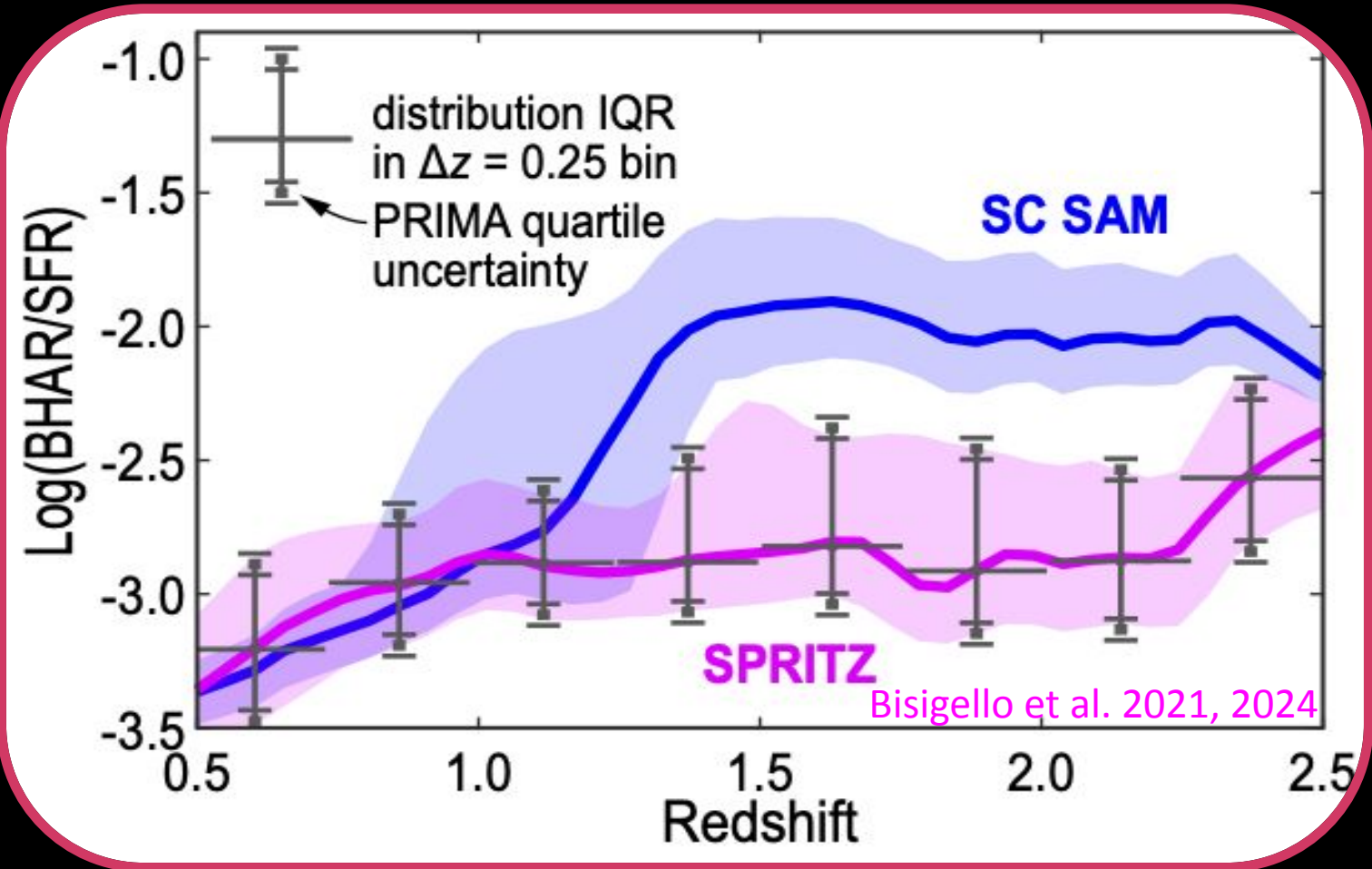
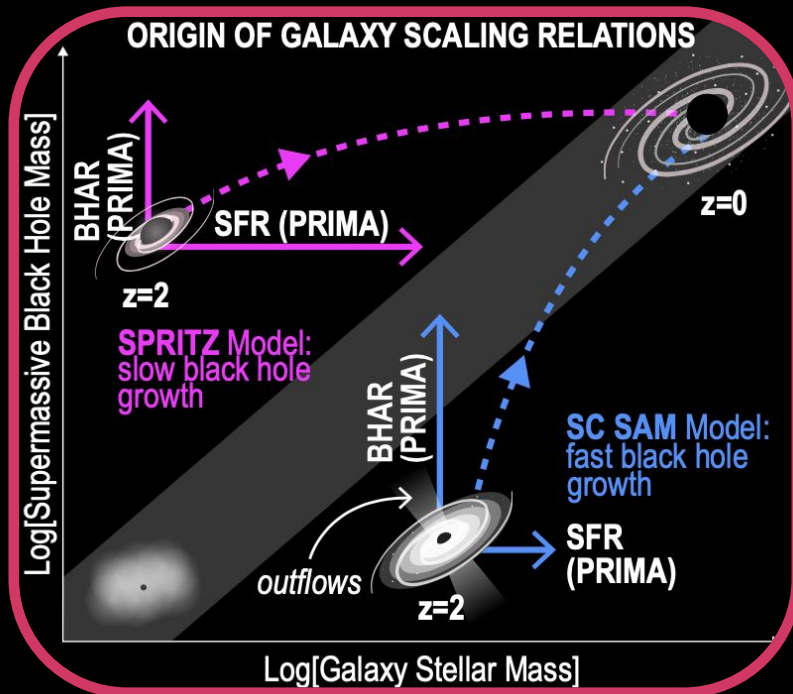
PRIMA will measure the black-hole accretion rates and star-formation rates in luminous galaxies since the peak epoch to map their pathway onto the local $M_{\text{star}}-M_{\text{BH}}$ relation



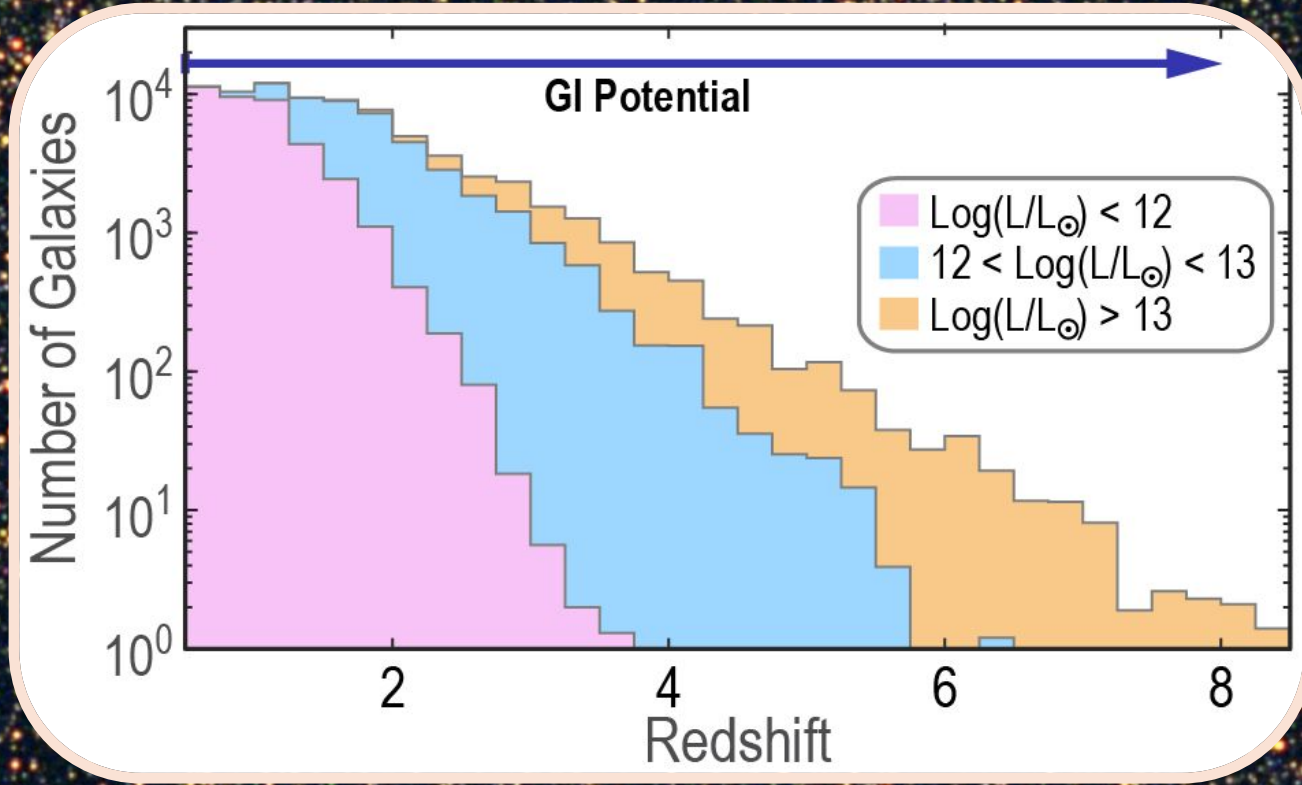


EVOLUTION OF GALACTIC ECOSYSTEMS

PRIMA will measure the scaling relation between black-hole accretion rate and star-formation rate in luminous galaxies since the peak epoch



3D Hyperspectral surveys: for every galaxy we get a full IR spectral energy distribution



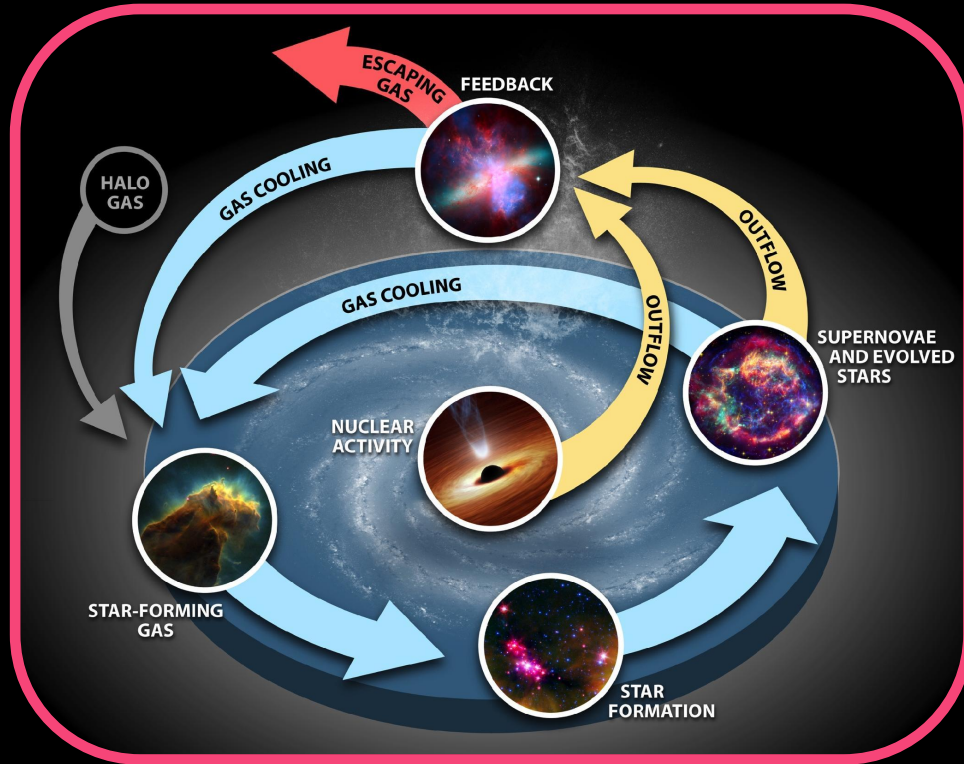
Deep and wide PRIMAgger surveys (1 sq. deg + 10 sq. deg) will yield full IR SEDs for ~60,000 galaxies down to L^*
-> tons of guest investigator science

See *PRIMA GO science book* for many projects that would utilize such survey data

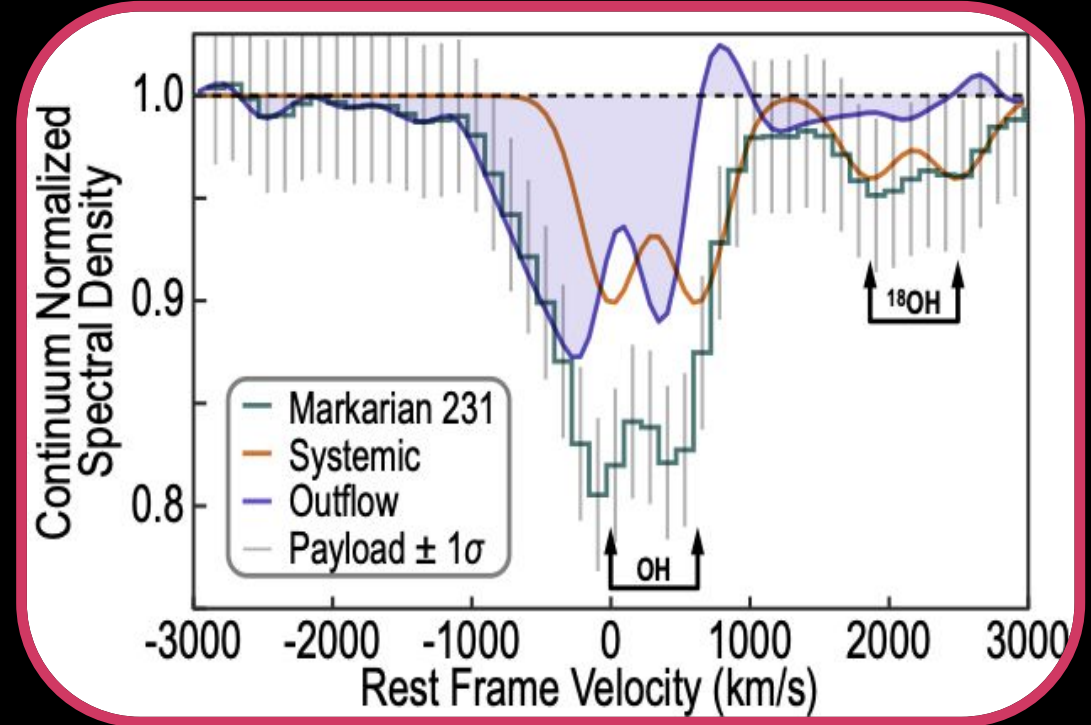


EVOLUTION OF GALACTIC ECOSYSTEMS

What is the role of outflows?



Outflows could be the link between star formation and black hole accretion



PRIMA/FIRESS high res: OH doublet absorption features (here $84 \mu\text{m}$ @ $z=1.5$; also 61, 71, 79 μm)

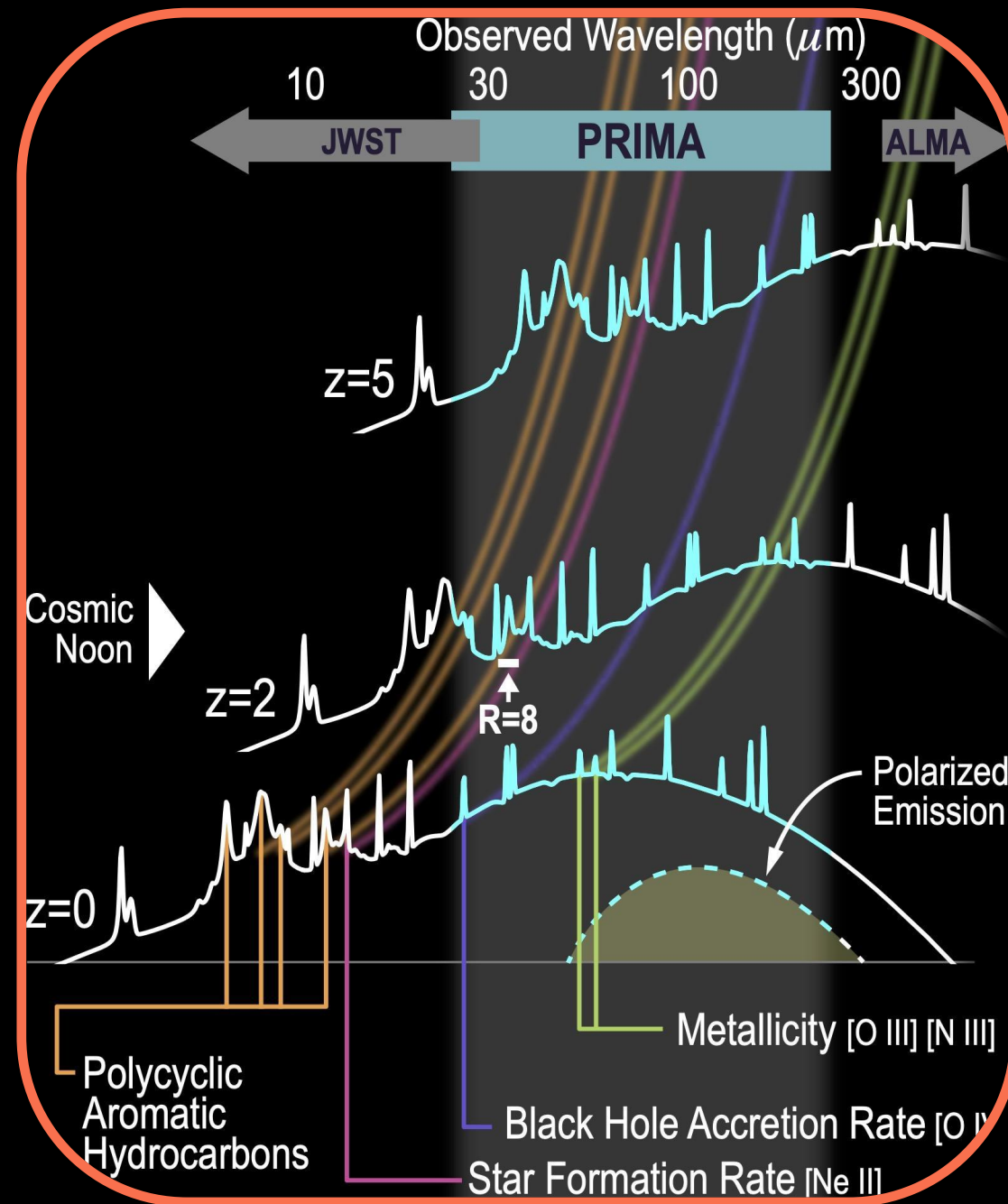
-> measure outflow velocity and mass



BUILDUP OF DUST AND METALS

Mid-infrared spectra provide crucial diagnostics of:

- dust properties (polarized emission)
- metallicity (FIR fine structure lines and PAHs)

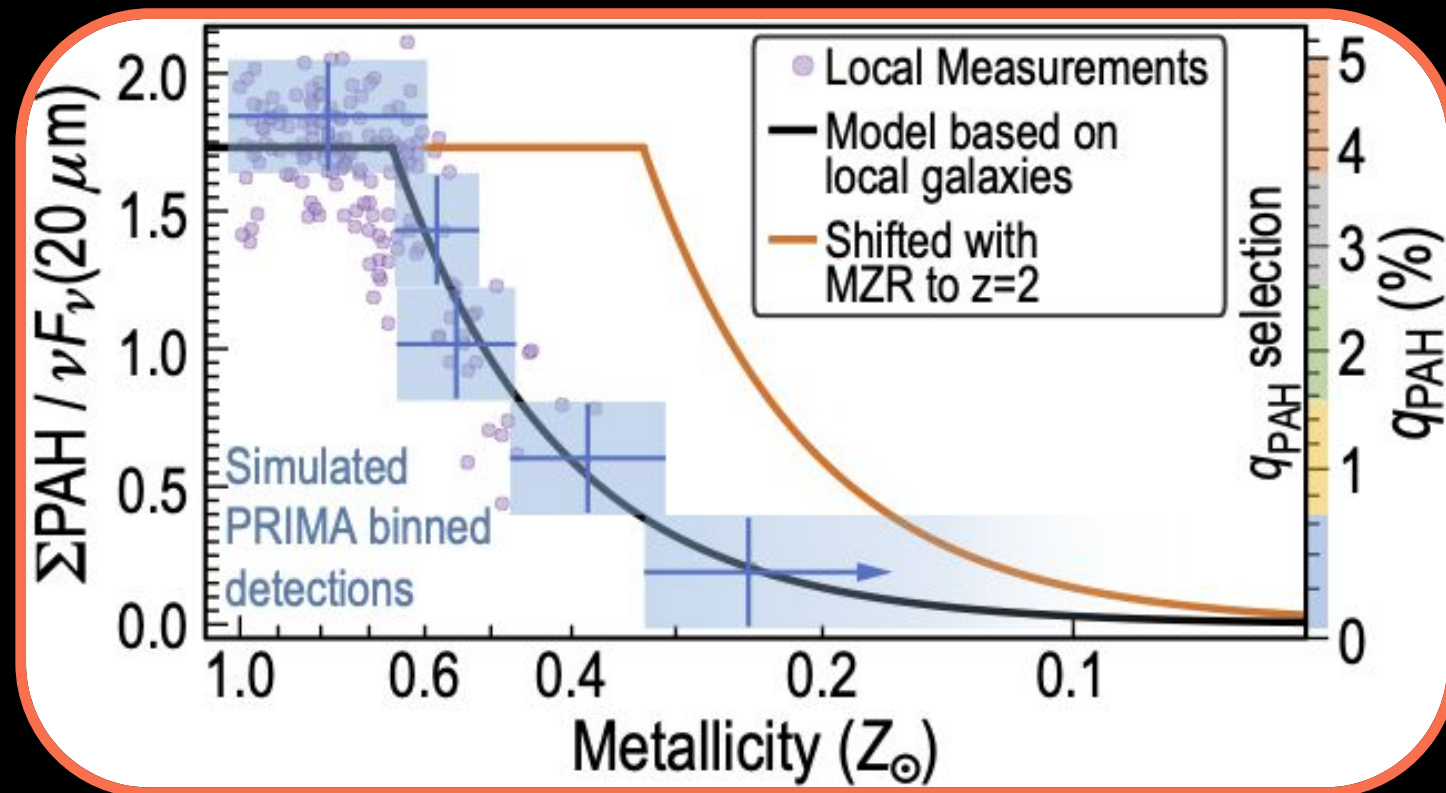




BUILDUP OF DUST AND METALS

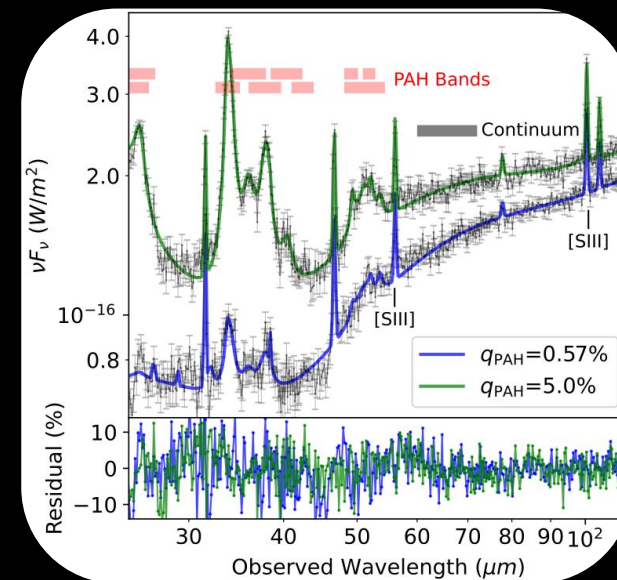
Has the relationship between PAHs and metals evolved since cosmic noon?

In the local universe, there a decrease in PAH emission at lower metallicities.



FIRESS will observe 100 $z=2$ galaxies to measure:

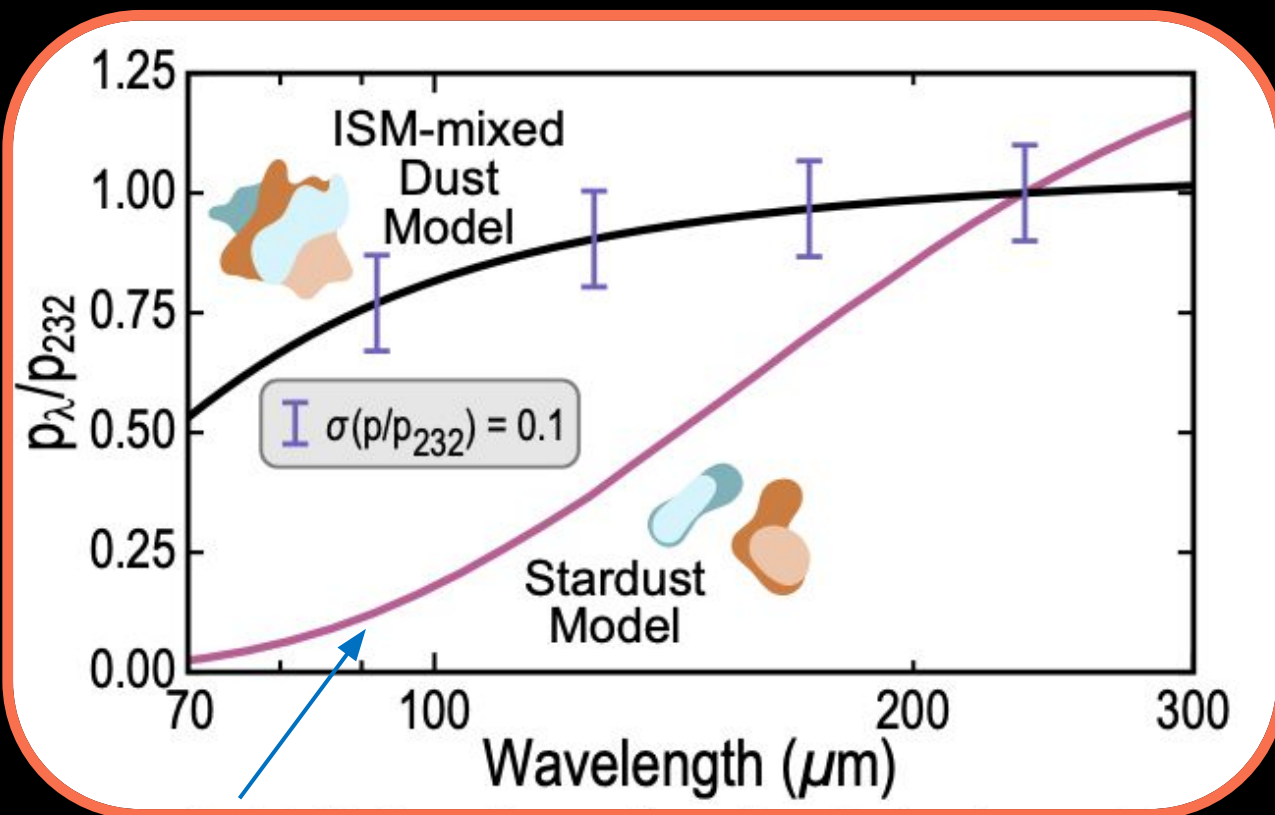
- Gas-phase abundances of O and N via [O III], [N III]
- q_{PAH} from rest-frame 11.3 and 12.7 μm





Interstellar Dust Grain Growth

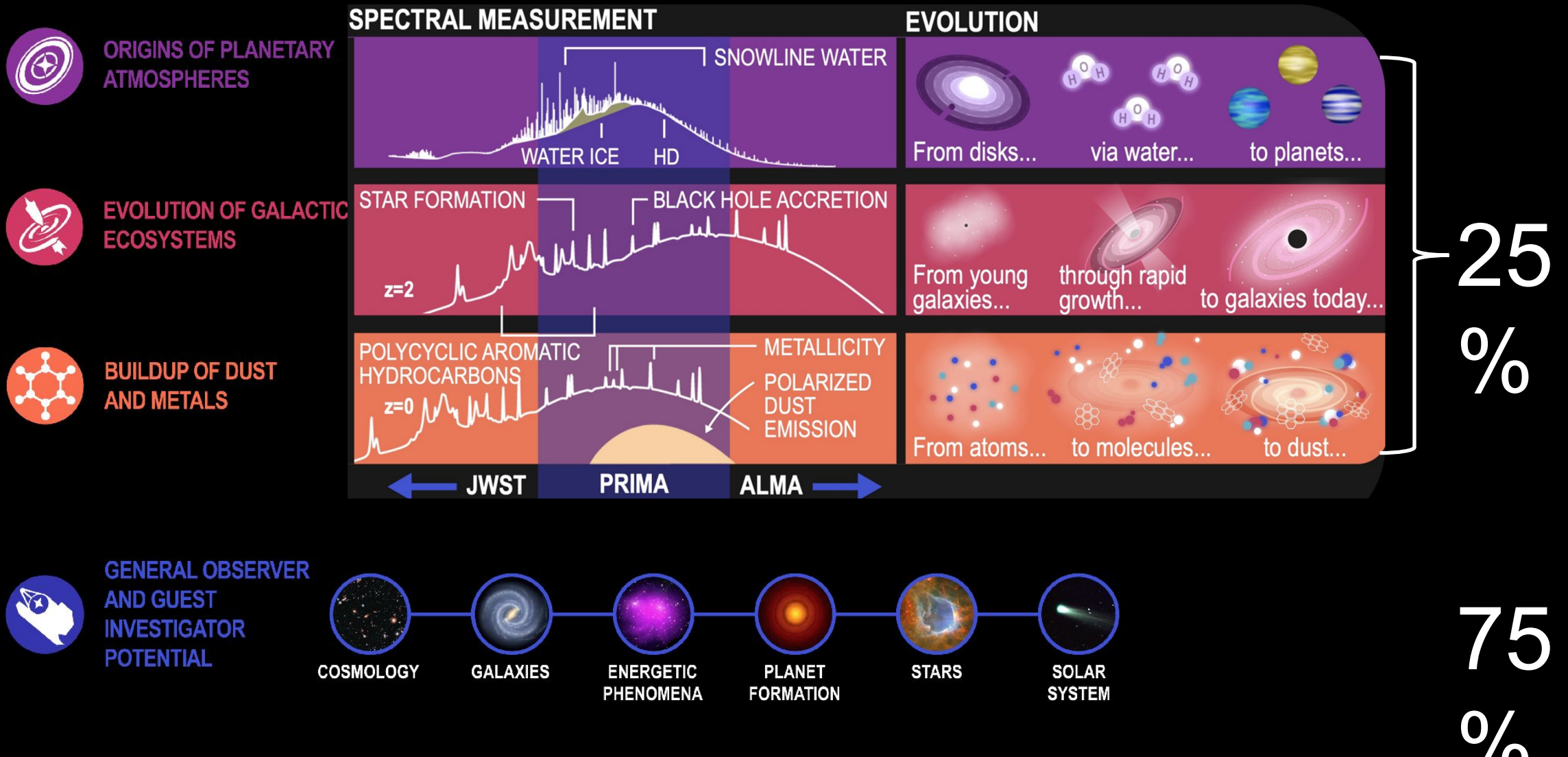
How does the structure of interstellar dust change across environments in the local universe?



Warm, C-rich grains unpolarized

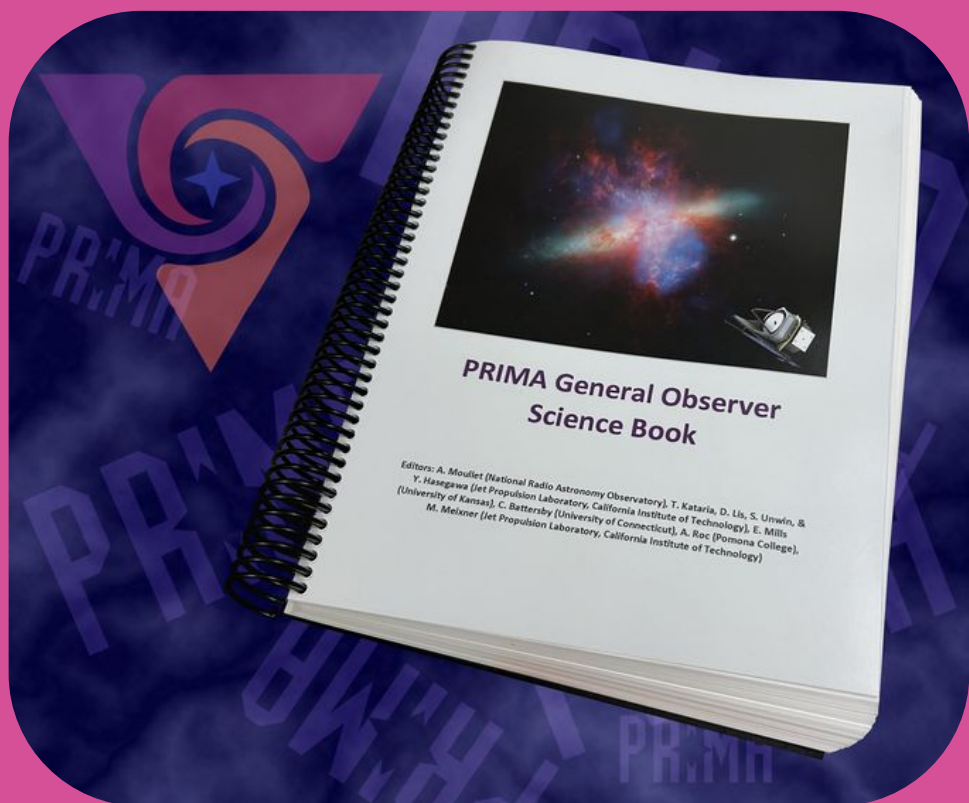
- Polarization:
 - Pristine stardust from C-rich AGB stars does not produce polarized emission.
 - Composite grains aggregating stardust with ISM-grown grains does.
- PRIMA will test if ISM grain growth rates are suppressed in low-metallicity galaxies/environments by imaging 31 local galaxies from 91-232 μm with polarization

PRIMA addresses Astro2020's 3 science goals for a far-IR probe and opens vast discovery space for the community



75% of the observing time on PRIMA will be for general observations

GO Book Volume 1 2023
arXiv:2310.20572



GO Book Volume 2 2025
arXiv:2511.10927



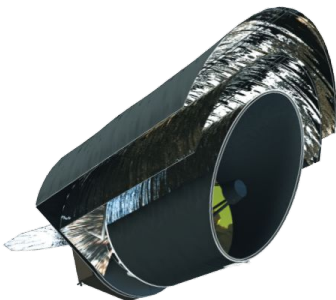
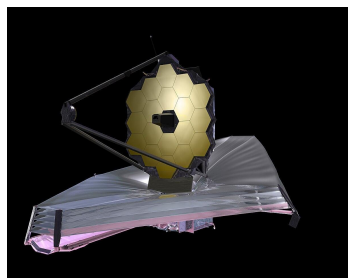
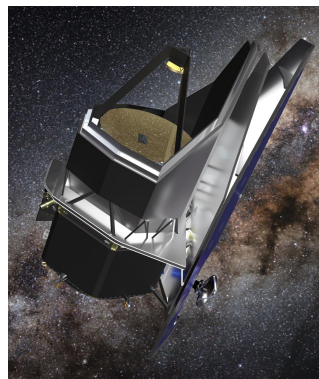
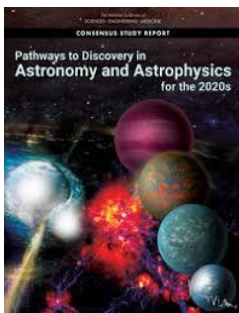
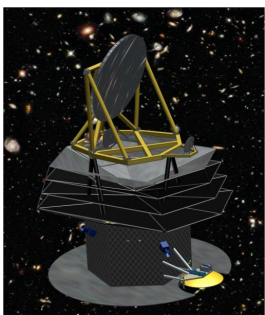
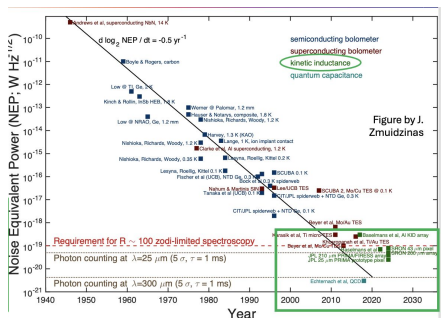
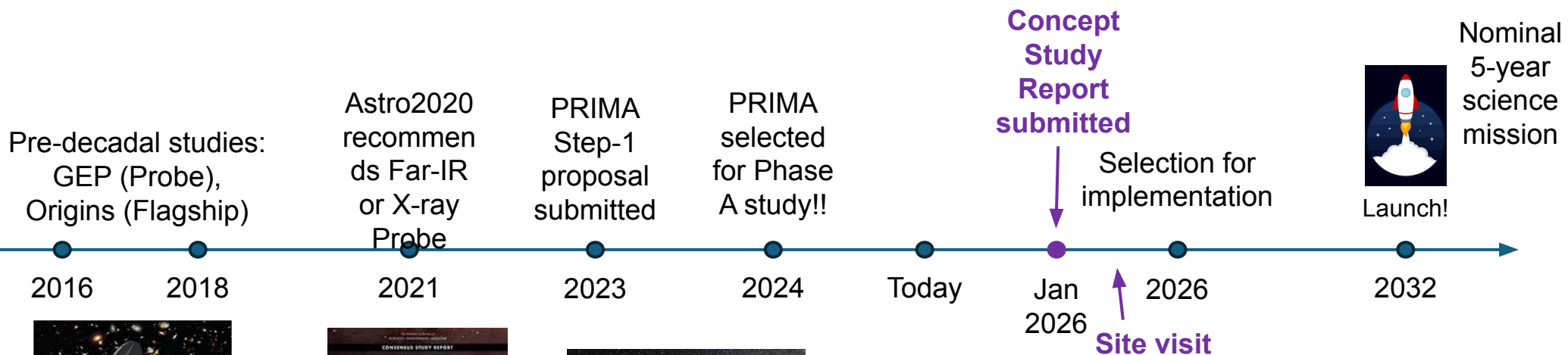
**PRIMA General Observer
Science Book Volume 2**



PRIMA Timeline

Foundation:

>20 yrs NASA investment in detector and cryocooler technology – KIDs, MIRI cryocooler, CADR and Heritage from previous IR missions: ISO, Spitzer, Herschel, (SPICA)



Why now?

1. Detector & cryocooler technology mature
2. Excellent complementarity to JWST & ALMA
3. Unprecedented sensitivity → vast discovery potential
4. Implementation feasible in 5 years