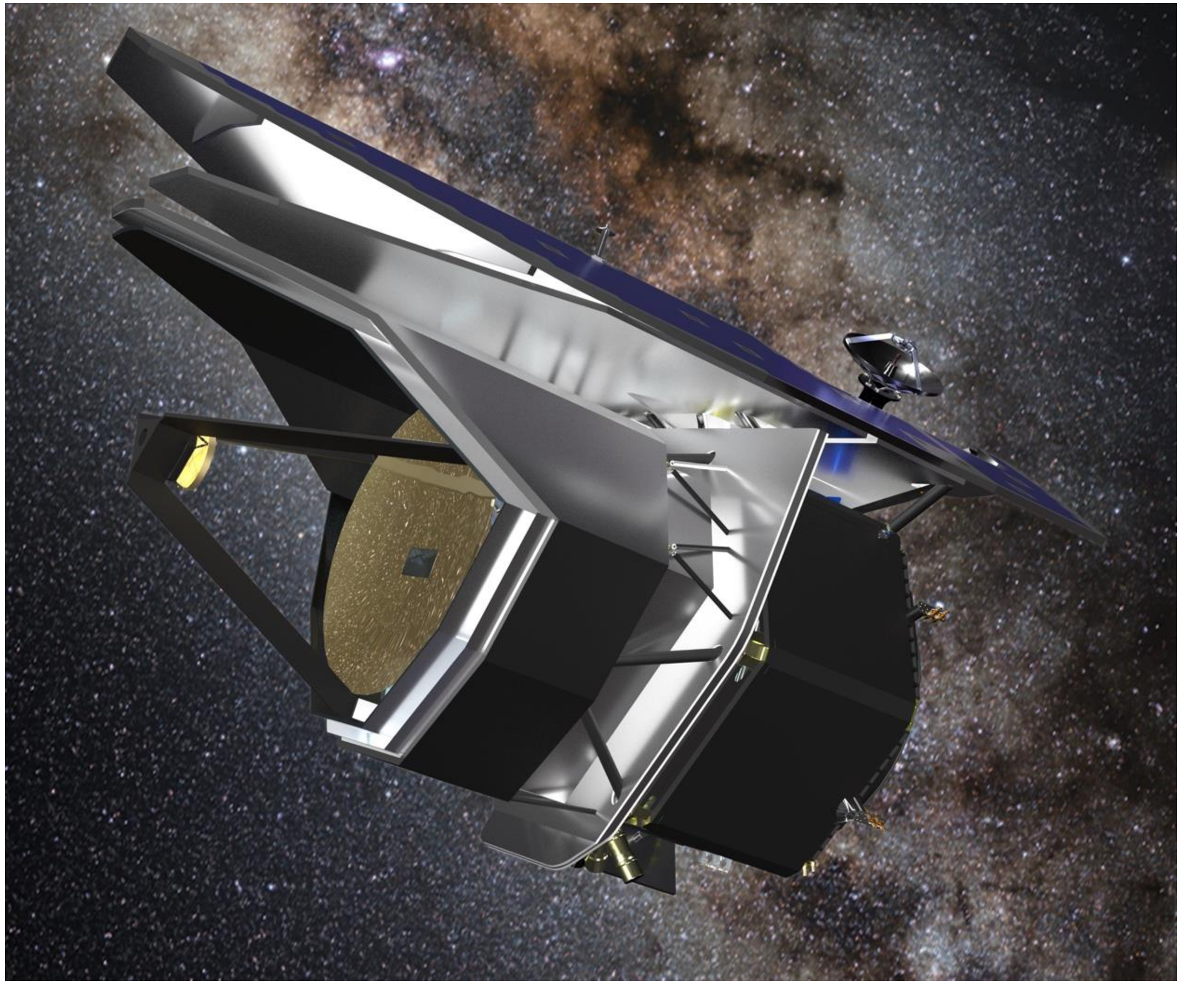
PRIMA *The PRobe far-Infrared Mission for Astrophysics*

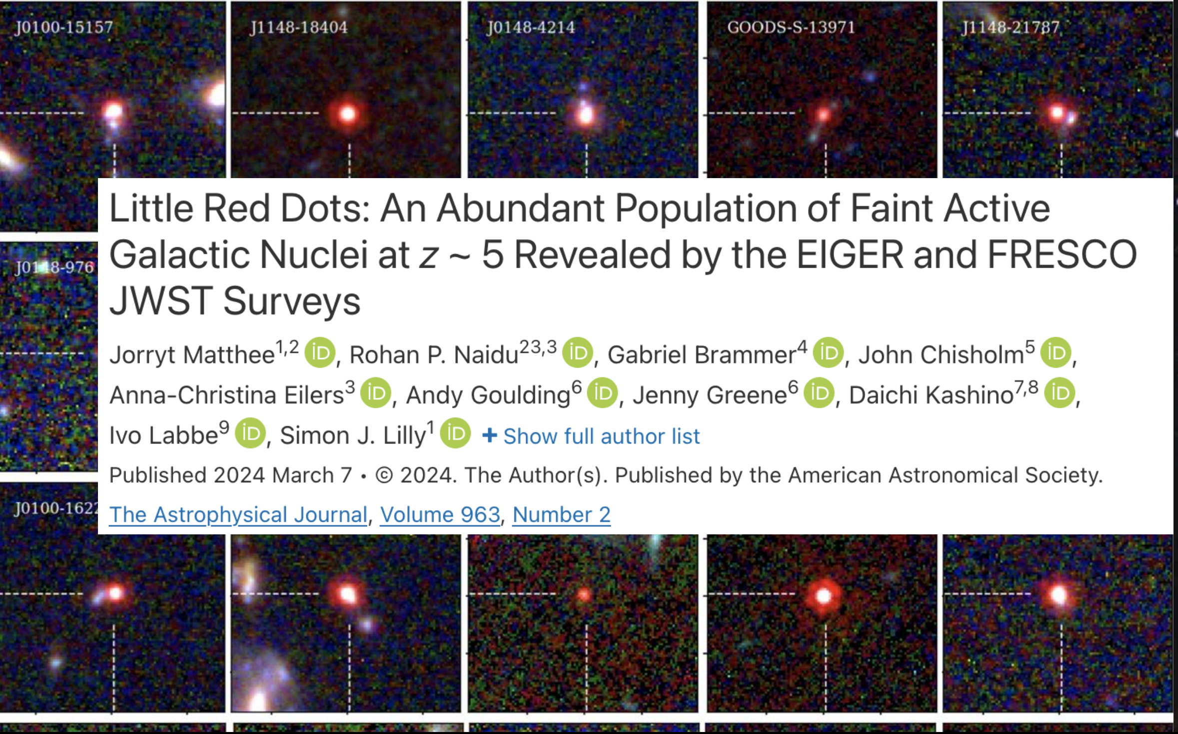


Jason Glenn, Principal Investigator, GSFC
Margaret Meixner, Deputy PI, JPL
Matt Bradford, Project Scientist, JPL
Klaus Pontoppidan, Deputy PI, JPL
Alexandra Pope, Science Lead, UMass Amherst
Tiffany Kataria, Deputy SL, JPL
Jenn Rocca, Proposal Capture Lead, JPL

Co-Is in person at this meeting:
Denis Burgarella, LAM
Laure Ciesla, LAM
Anna Di Giorgio, INAF
Carlotta Gruppioni, INAF OAS
Thomas Henning, MPIA
Oliver Krause, MPIA
Marc Sauvage, CEA
Johannes Staguhn, GSFC

Full list of co-Is:

Jet Propulsion Laboratory, California Institute of Technology · NASA Goddard Space Flight Center · BAE SYSTEMS · ipac · cnes · asi agenzia spaziale italiana · DLR · SRON · NG · NASA Marshall Space Flight Center

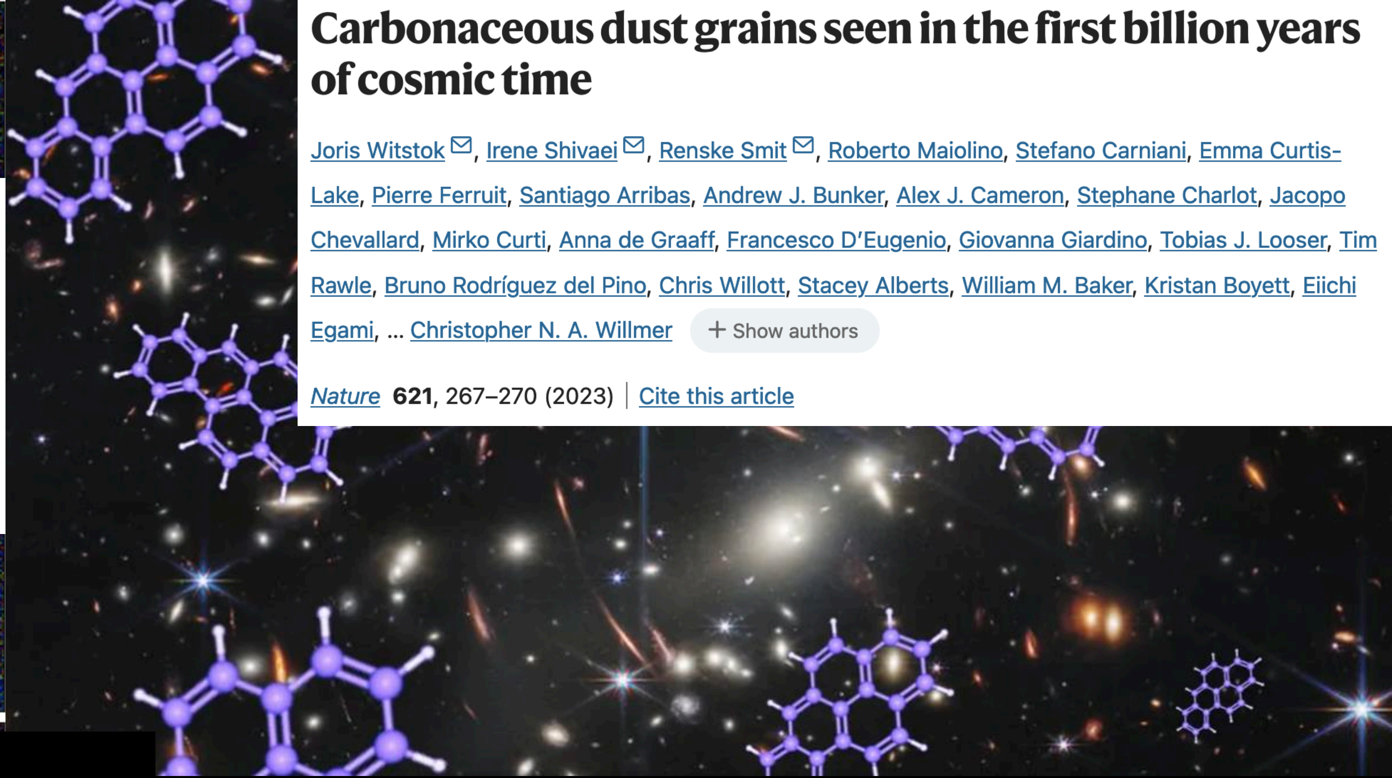


Little Red Dots: An Abundant Population of Faint Active Galactic Nuclei at $z \sim 5$ Revealed by the EIGER and FRESCO JWST Surveys

Jorryt Matthee[1,2], Rohan P. Naidu[23,3], Gabriel Brammer[4], John Chisholm[5], Anna-Christina Eilers[3], Andy Goulding[6], Jenny Greene[6], Daichi Kashino[7,8], Ivo Labbe[9], Simon J. Lilly[1] + Show full author list

Published 2024 March 7 •

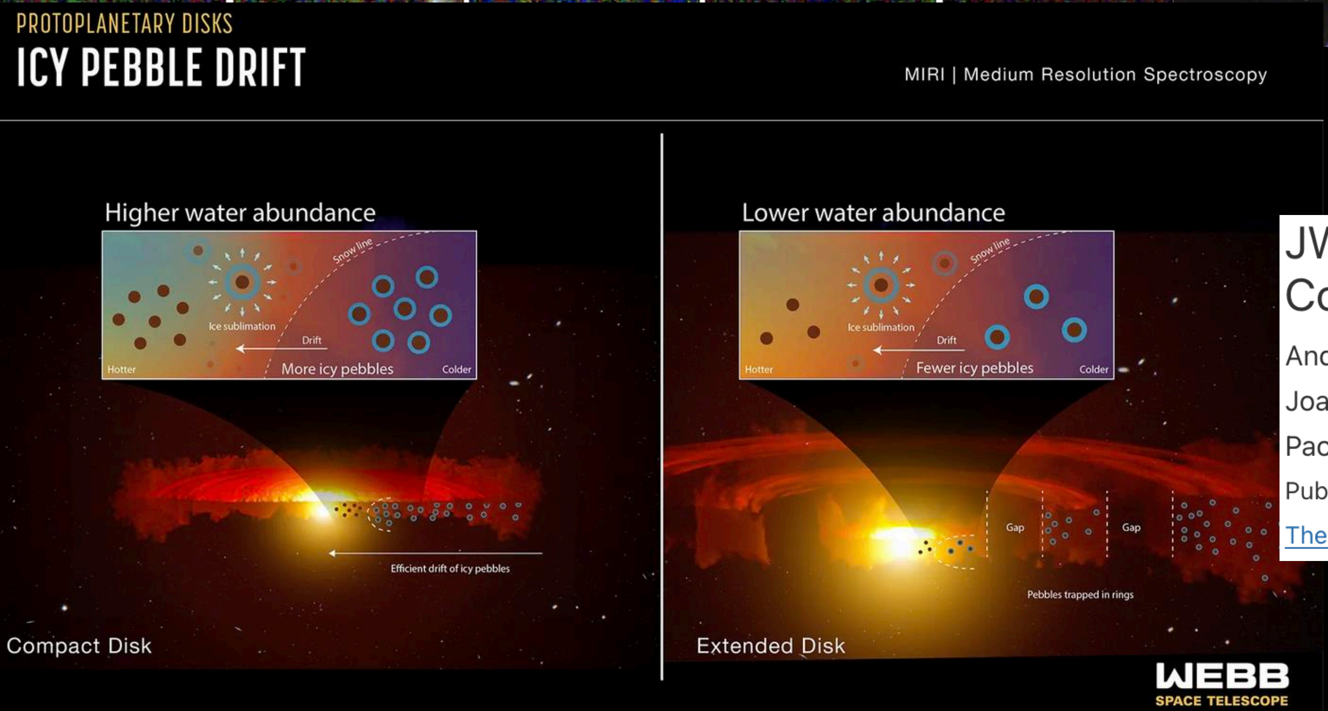
The Astrophysical Journal, Volume 963, Number 2



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

Joris Witstok, Irene Shivaei, 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 Banzatti[1], Klaus M. Pontoppidan[2], John S. Carr[3], Evan Jellison[1], Ilaria Pascucci[4], Joan R. Najita[5], Carlos E. Muñoz-Romero[7], Karin I. Öberg[6], Anusha Kalyaan[1], Paola Pinilla[7] + Show full author list

Published 2023 November 8 •

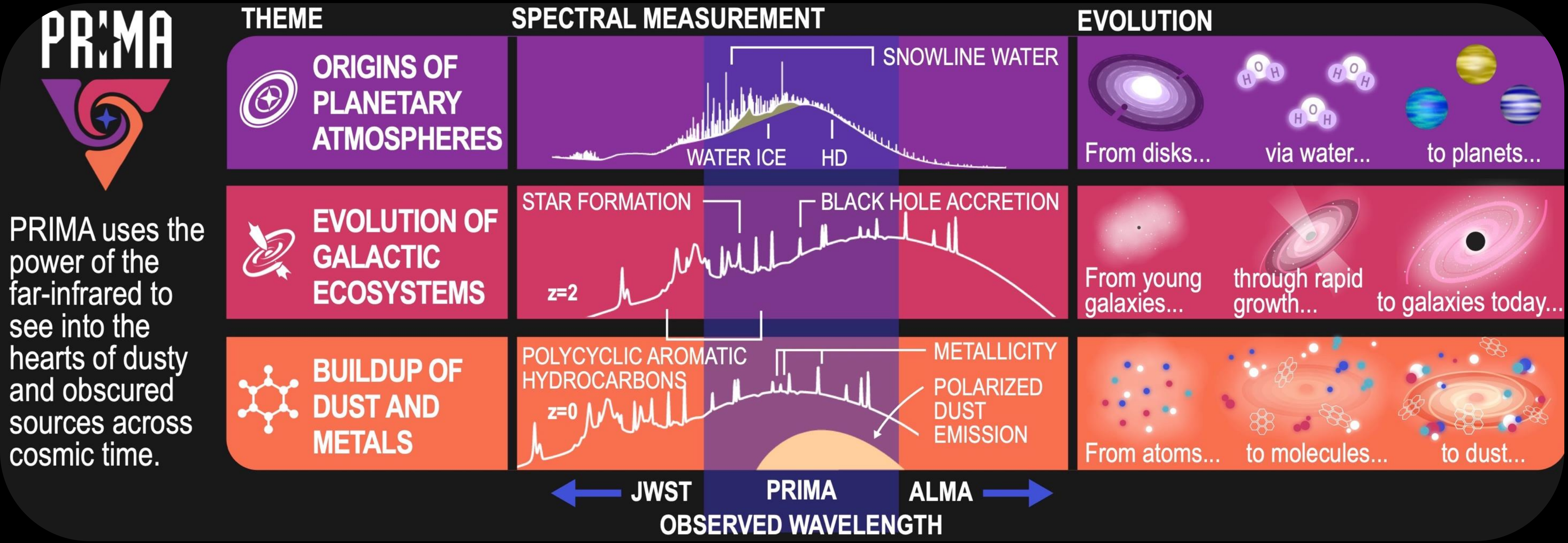
The Astrophysical Journal Letters, Volume 957, Number 2

Astro2020 Decadal Survey Section 7.5.3.3 :

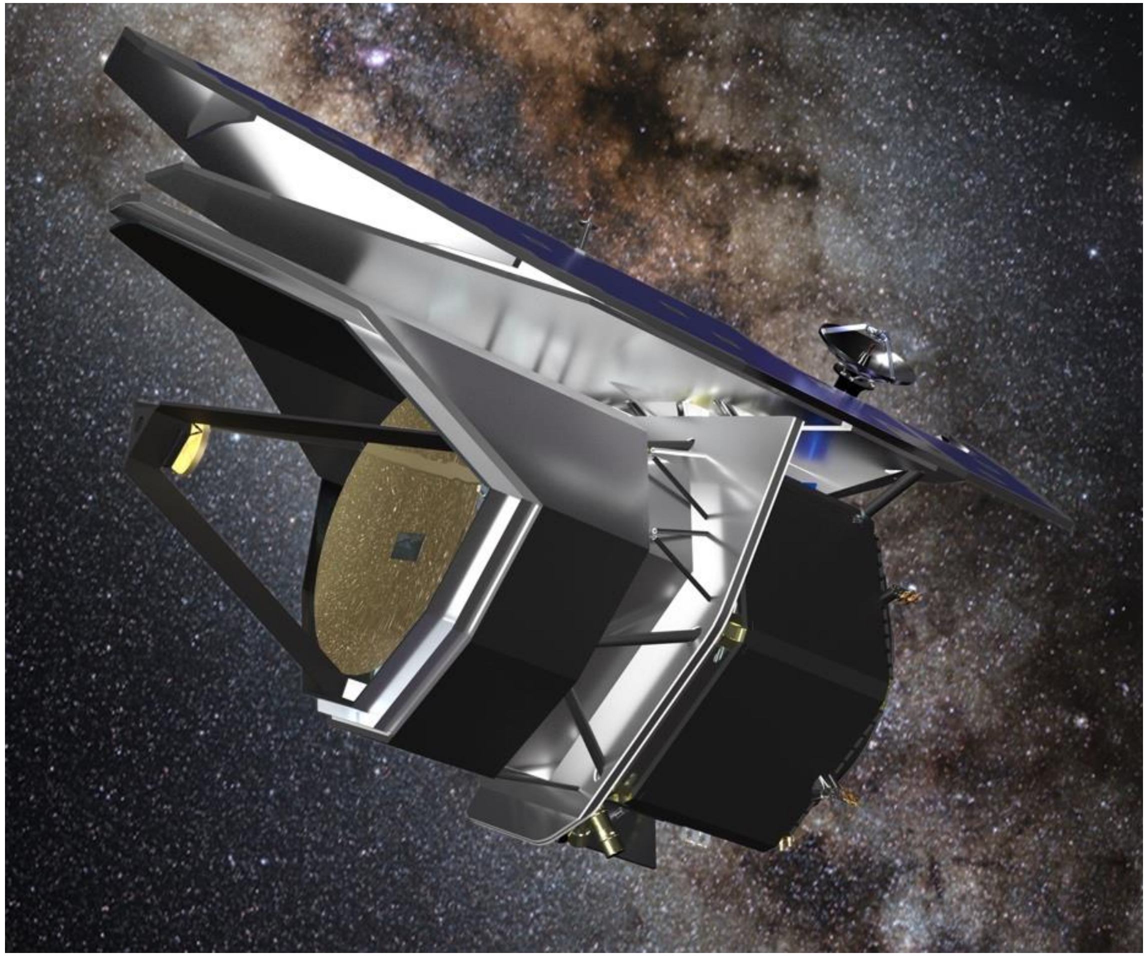
and a probe scale mission is an extremely timely and compelling opportunity to do so. These scientific areas include tracing the astrochemical signatures of planet formation (within and outside of our own Solar System), measuring the formation and buildup of galaxies, heavy elements, and interstellar 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 :

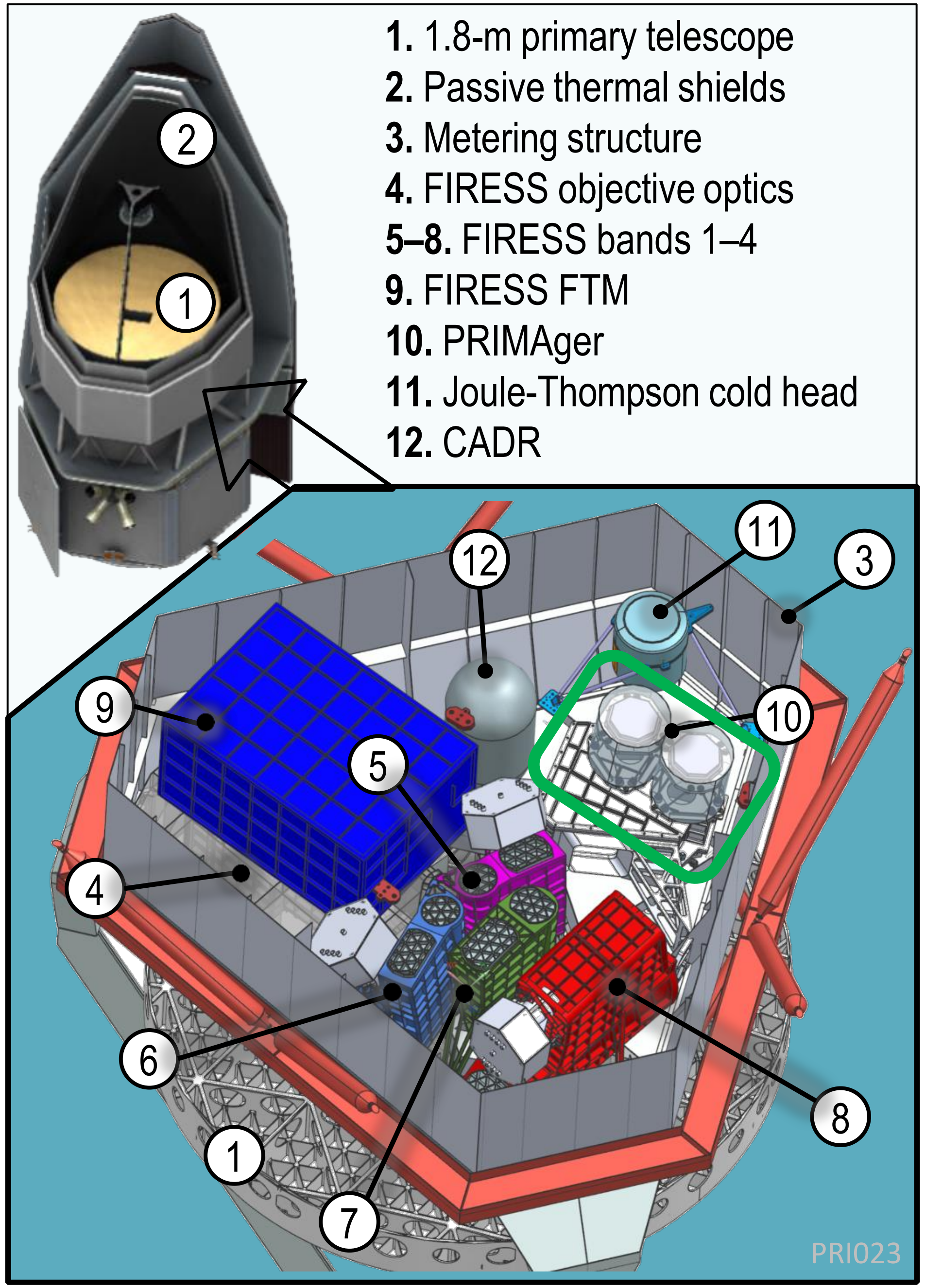
> and a probe scale mission is an extremely timely and compelling opportunity to do so. These scientific areas include tracing the astrochemical signatures of planet formation (within and outside of our own Solar System), measuring the formation and buildup of galaxies, heavy elements, and interstellar 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



PRIMA

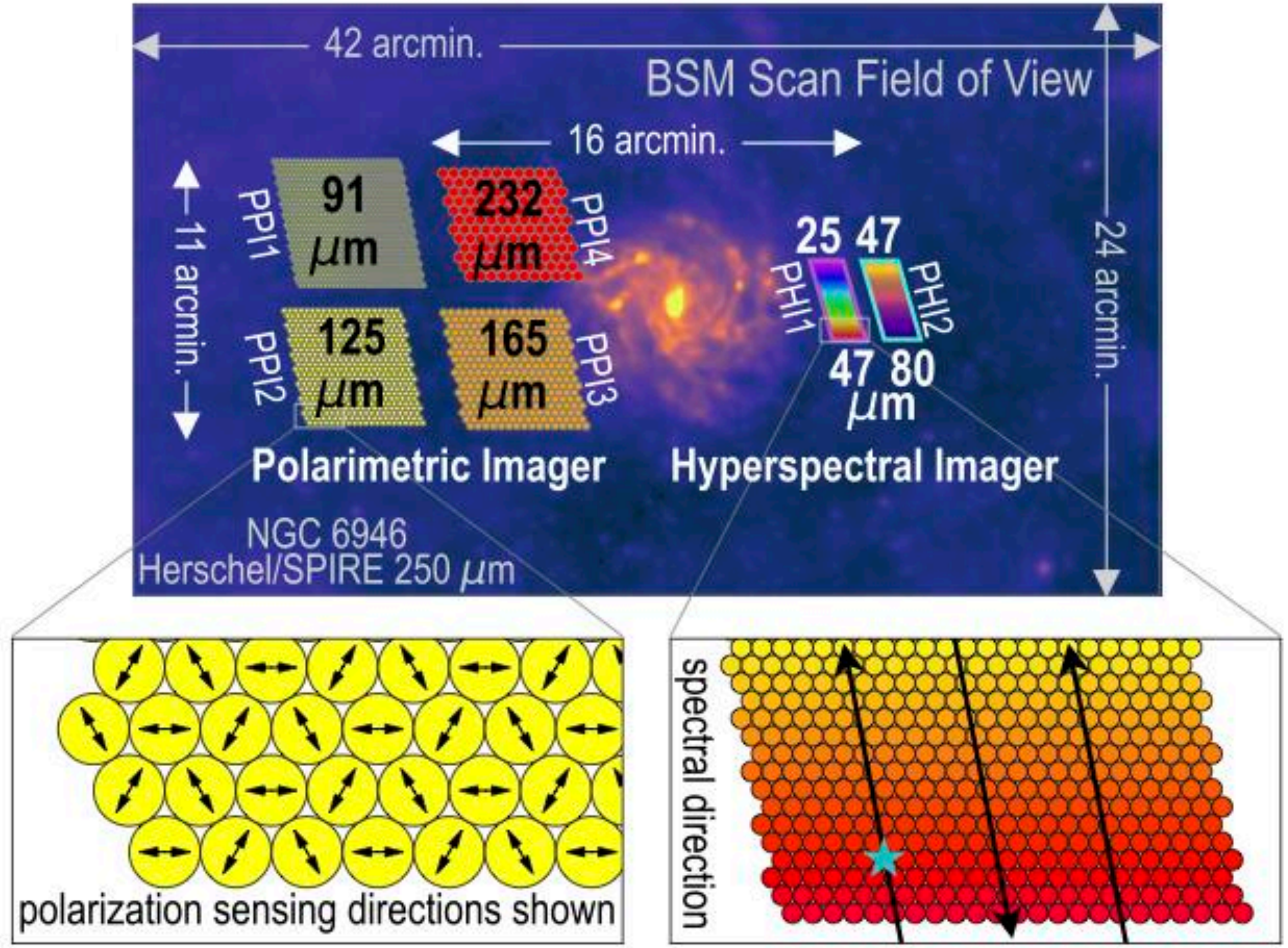


Telescope	1.8-m, all aluminum, 4.5 Kelvin
PRIMAger Imager & polarimeter	R = 10 hyperspectral imaging 25-80 μm R= 4 imaging & polarimetry 91-261 μm
FIRESS Spectrometer	R > 85 spectroscopy 24-235 μm High-Res mode R = 4,400 x (112$\mu m/\lambda$)
Detectors	100 mK KID arrays (~12k total)
Data	IPAC
Orbit	Earth-Sun L2
Launch	2032
Observations	75% GO, 25% PI (→ GI)



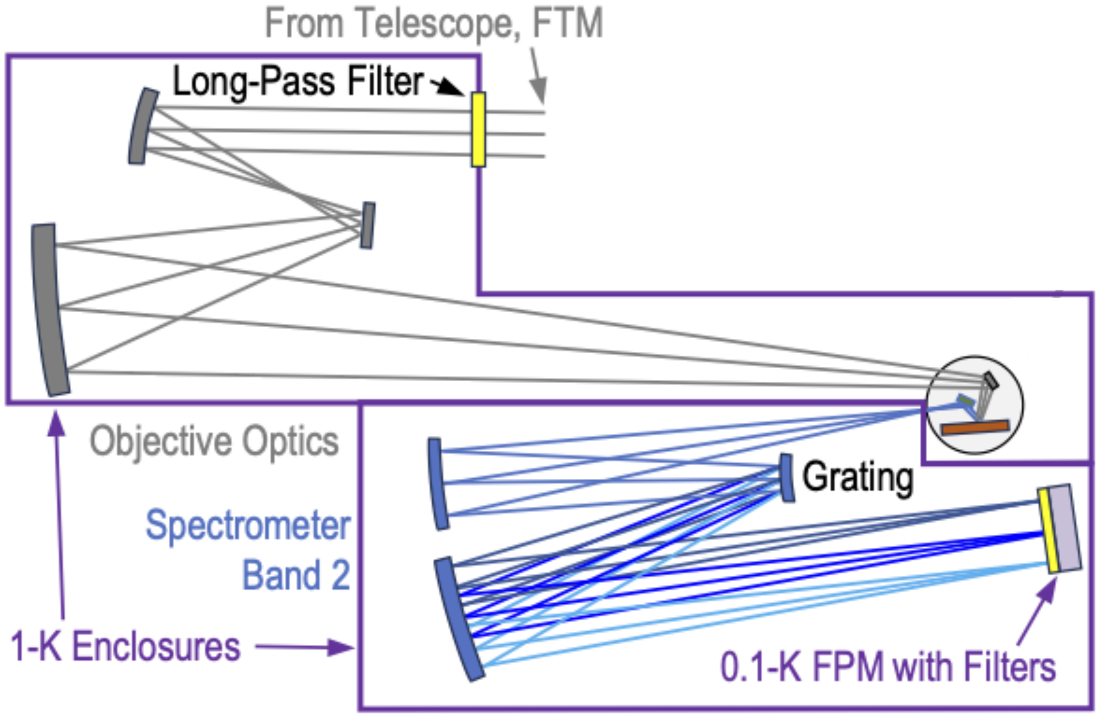
PRIMAger (French / Dutch contribution)

- Two R=10 Hyperspectral focal planes using linear variable filters: (24 – 80 μm, PHI1/PHI2)
- Four R=4 polarimetric imaging arrays: (80 – 235 μm, PPI1-4)
- 3993 total pixels

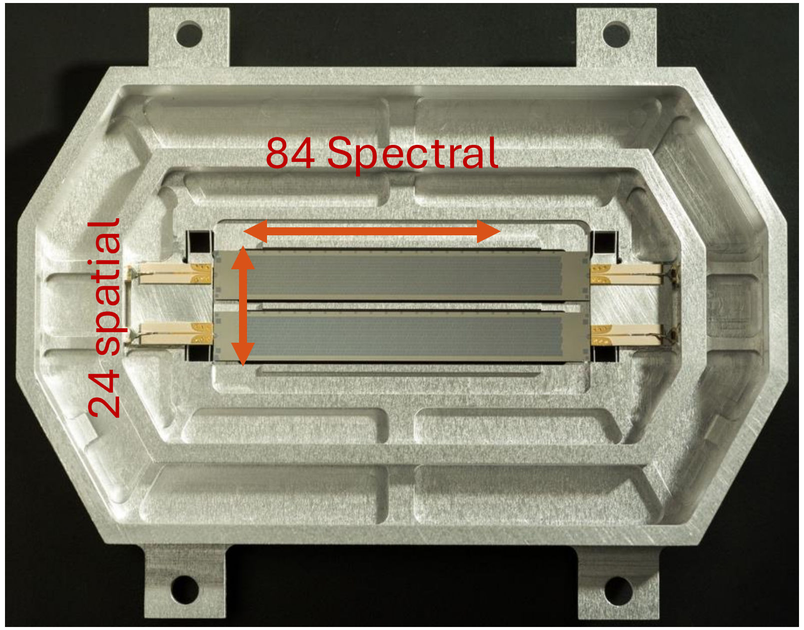


FIRESS (JPL)

- 4 slit-fed grating modules giving R ~ 100, greater than 85 everywhere (including sampling and grating intrinsic R)
- 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 x ($112\mu m/\lambda$)

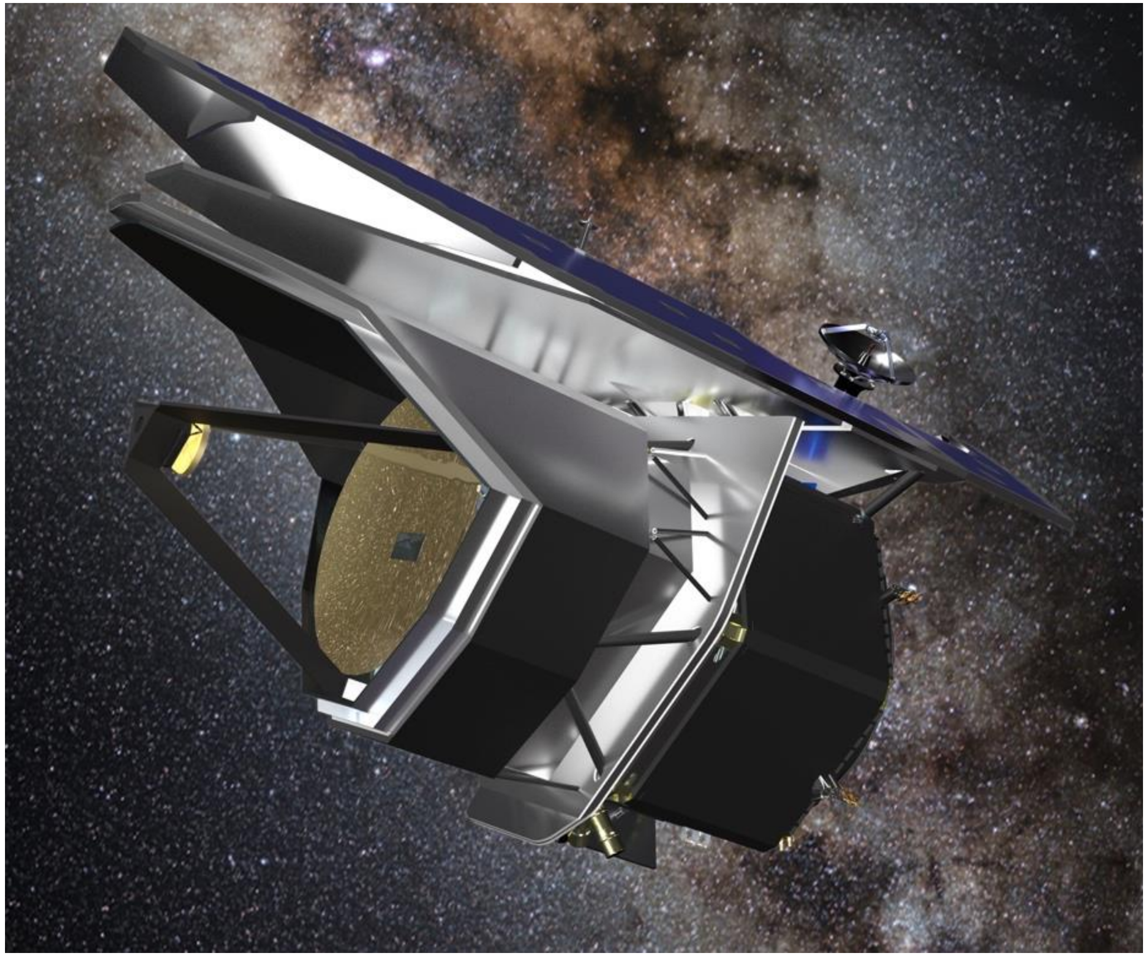


Parameter	Band 1	Band 2	Band 3	Band 4
Spectral range (µm)	24–43	42–76	74–134	130–235
Spectral sampling (µm)	0.23	0.41	0.73	1.29
Resolving power	95-150	85-120	90-125	95-130
Array format per band	24 spatial ×84 spectral pix, 900-µm pitch			
Pix size on sky (arcsec)	7.6		12.7	22.9
Pix pitch ratio to B1,2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



Prototype array in flight-like package

PRIMA



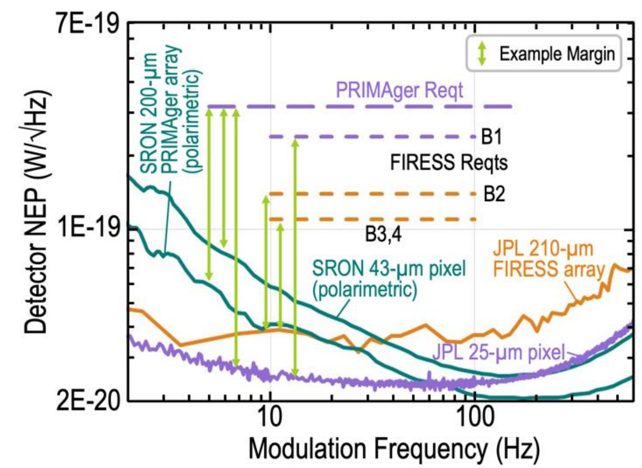
Telescope	1.8-m, all aluminum, 4.5 Kelvin
PRIMAger Imager & polarimeter	R = 10 hyperspectral imaging 25-80 μm R= 4 imaging & polarimetry 91-261 μm
FIRESS Spectrometer	R > 85 spectroscopy 24-235 μm High-Res mode R = 4,400 x (112μm/λ)
Detectors	100 mK KID arrays (~12k total)
Data	IPAC
Orbit	Earth-Sun L2
Launch	2032
Observations	75% GO, 25% PI (→ GI)

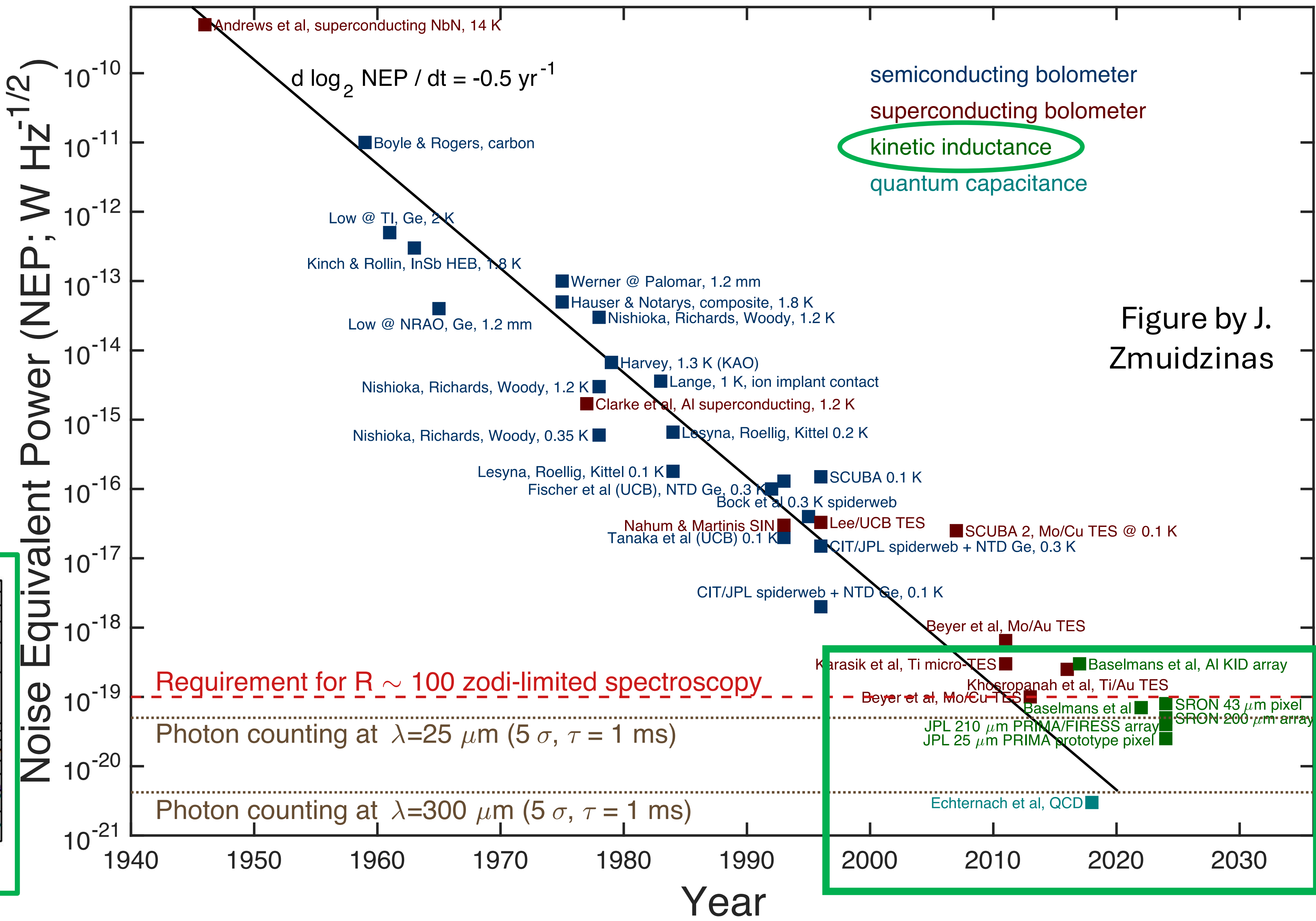
Why Now?

→ Far-IR Detector Technology

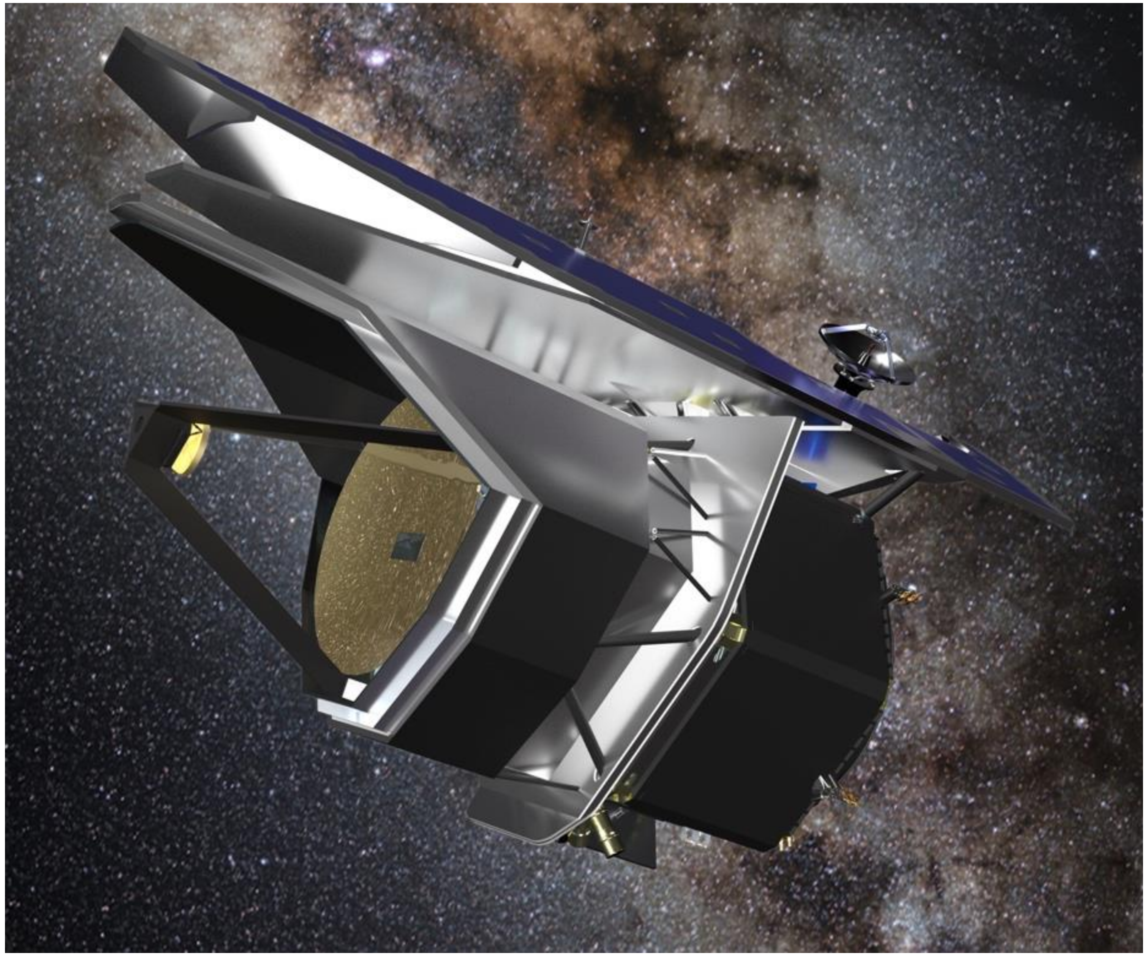
Sensitivities of far-IR detectors have doubled every ~2 years for 75 years!

PRIMA detectors exceed performance requirements over the full wavelength range.



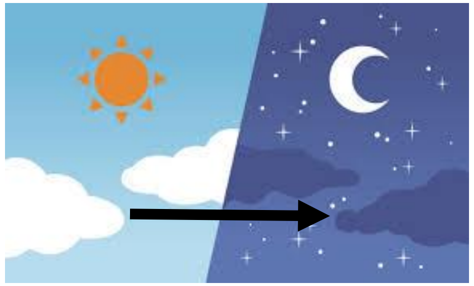


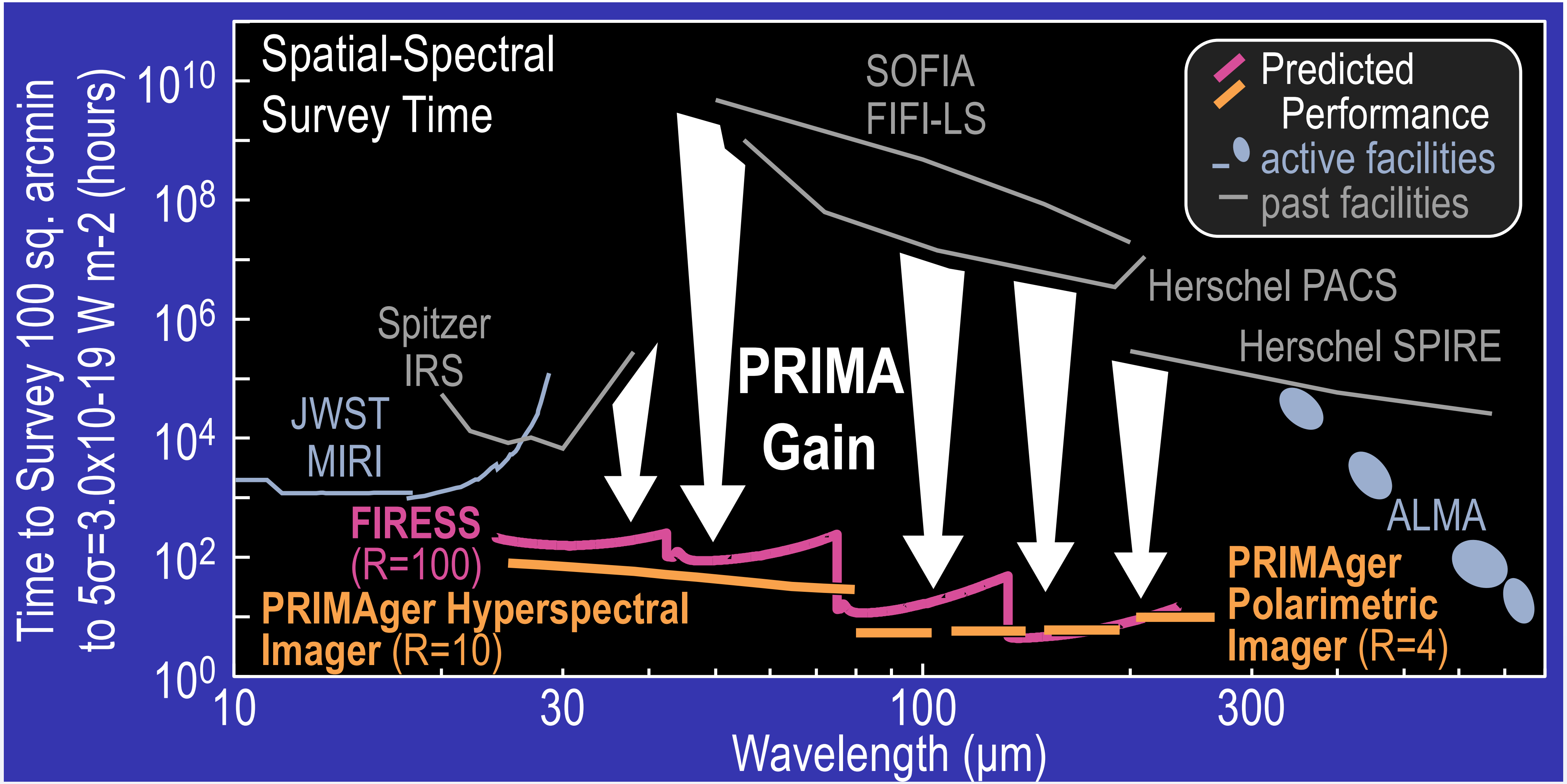
PRIMA



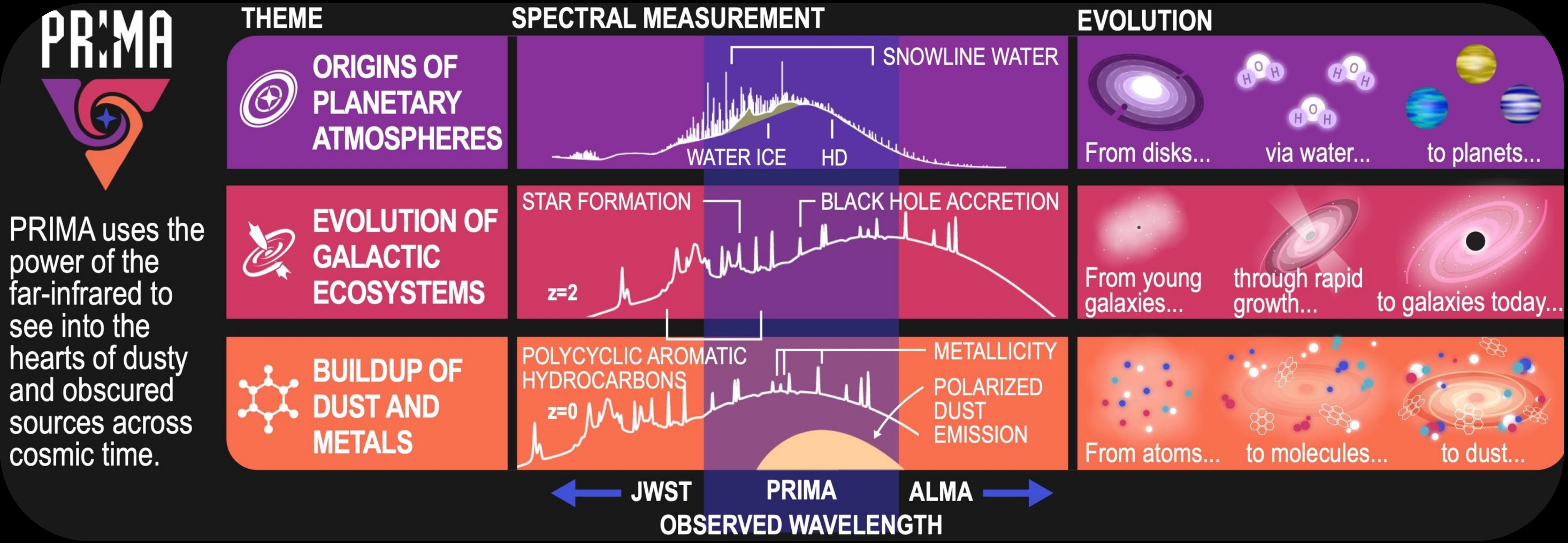
Telescope	1.8-m, all aluminum, 4.5 Kelvin
PRIMAger Imager & polarimeter	R = 10 hyperspectral imaging 25-80 μm R= 4 imaging & polarimetry 91-261 μm
FIRESS Spectrometer	R > 85 spectroscopy 24-235 μm High-Res mode R = 4,400 x (112μm/λ)
Detectors	100 mK KID arrays (~12k total)
Data	IPAC
Orbit	Earth-Sun L2
Launch	2032
Observations	75% GO, 25% PI (→ GI)

PRIMA makes massive gains in sensitivity



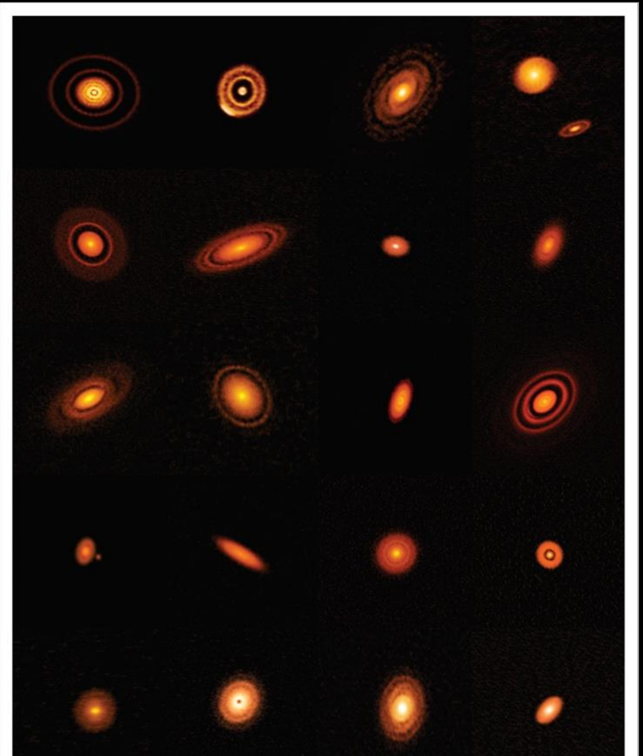


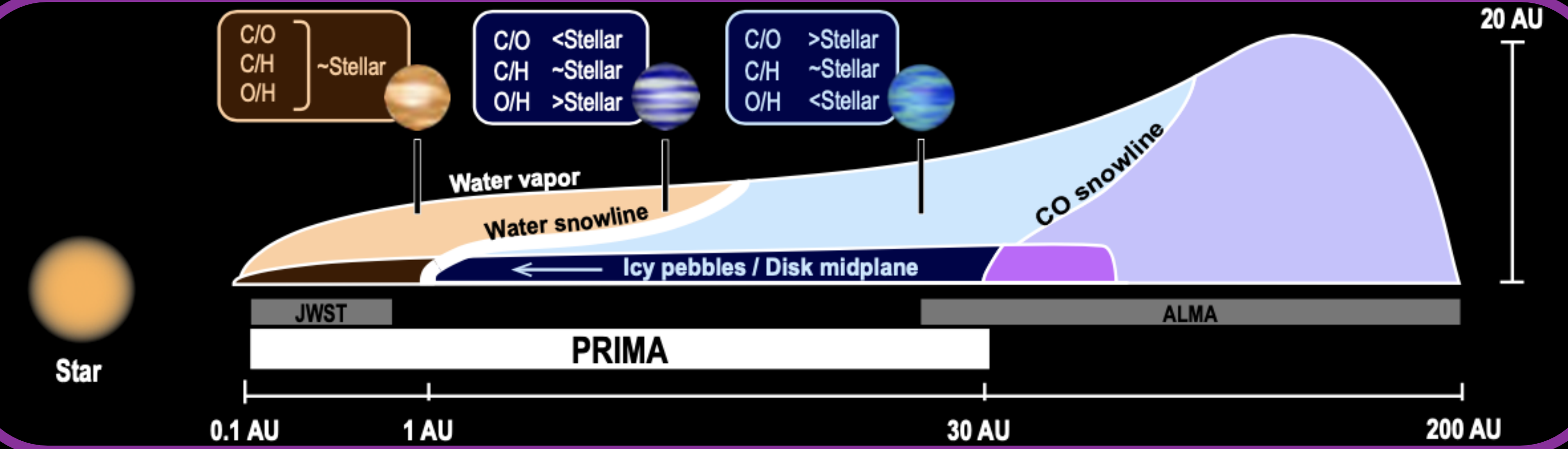
PRIMA PI science

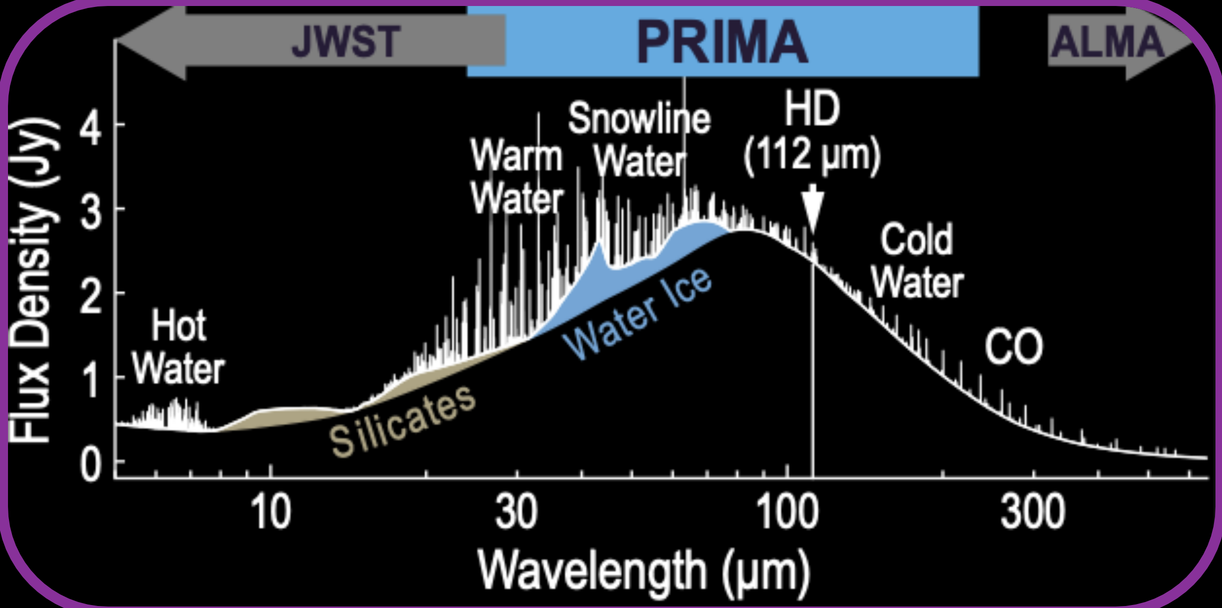


ORIGINS OF PLANETARY ATMOSPHERES

Protoplanetary disk structure is linked to the formation of exoplanets


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



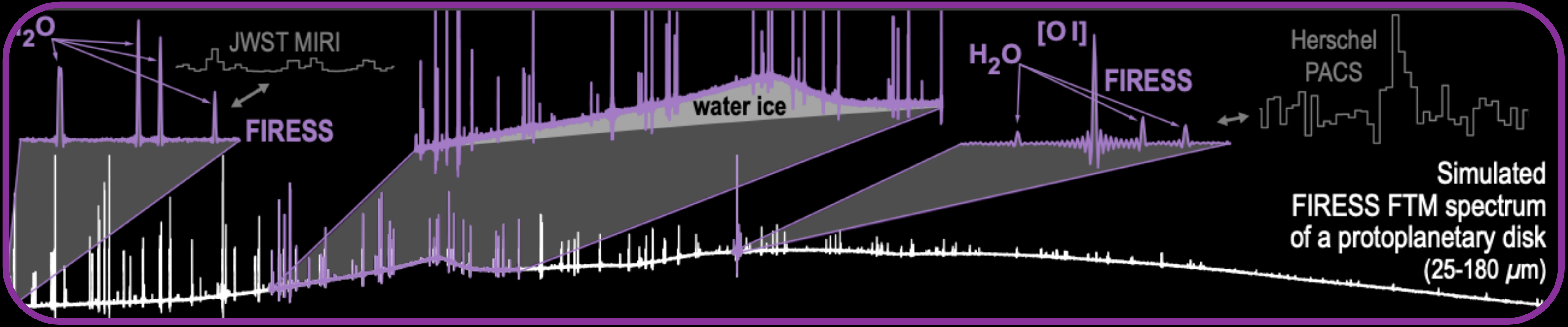


Unknowns and uncertainties

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

ORIGINS OF PLANETARY ATMOSPHERES

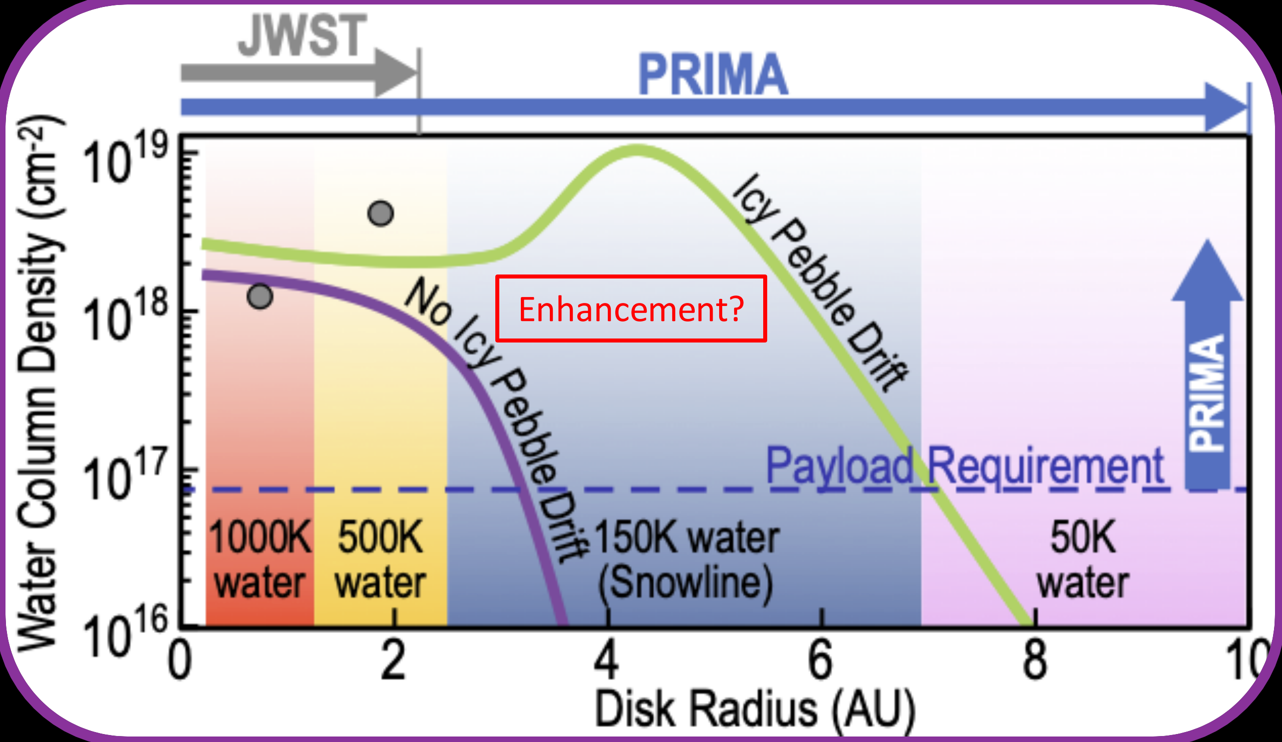
PRIMA will measure the HD mass and water content in 200 protoplanetary disks with high-resolution spectra

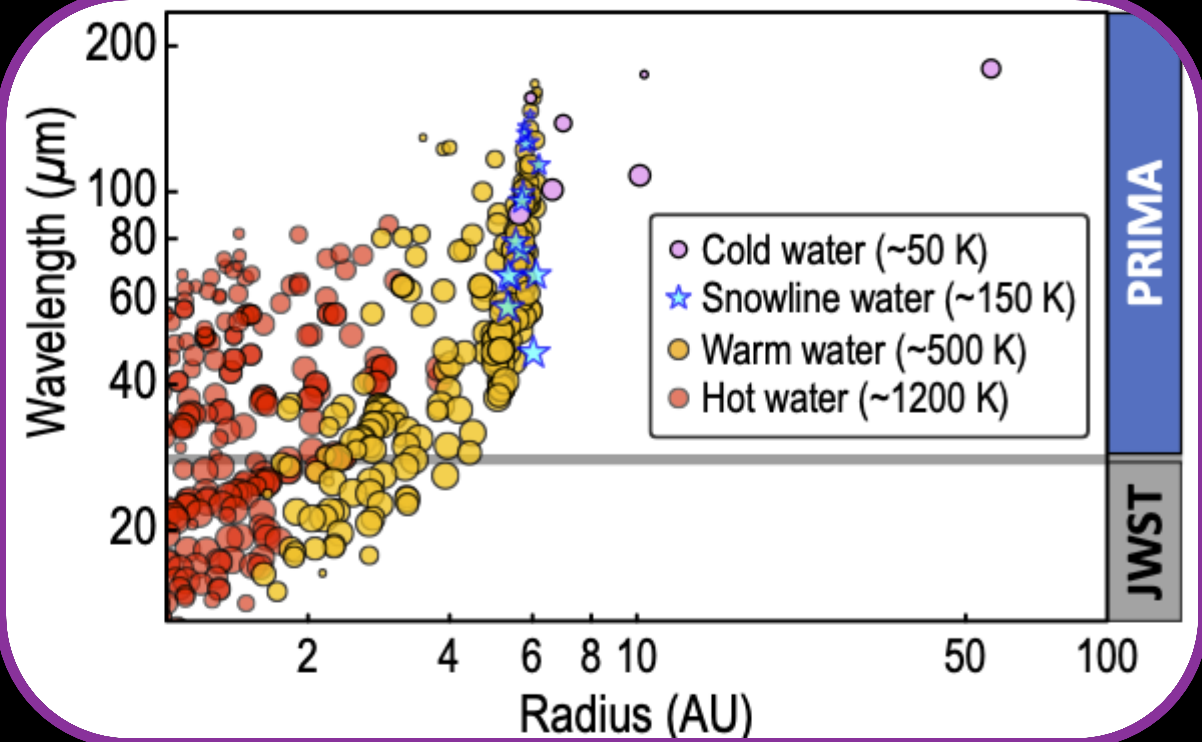


ORIGINS OF PLANETARY ATMOSPHERES

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

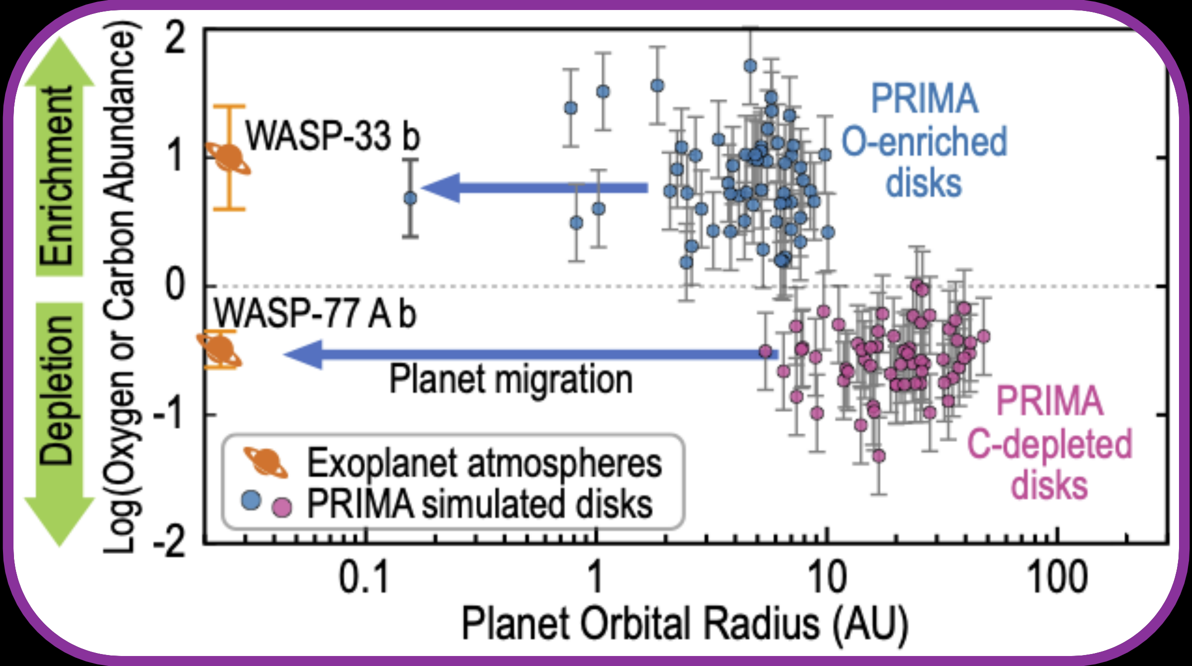
PRIMA/FIRESS FTM will measure the water column density to distinguish models with and without icy pebble drift by observing a wide range of water transitions to study spectral line energy distributions in 200 disks





ORIGINS OF PLANETARY ATMOSPHERES

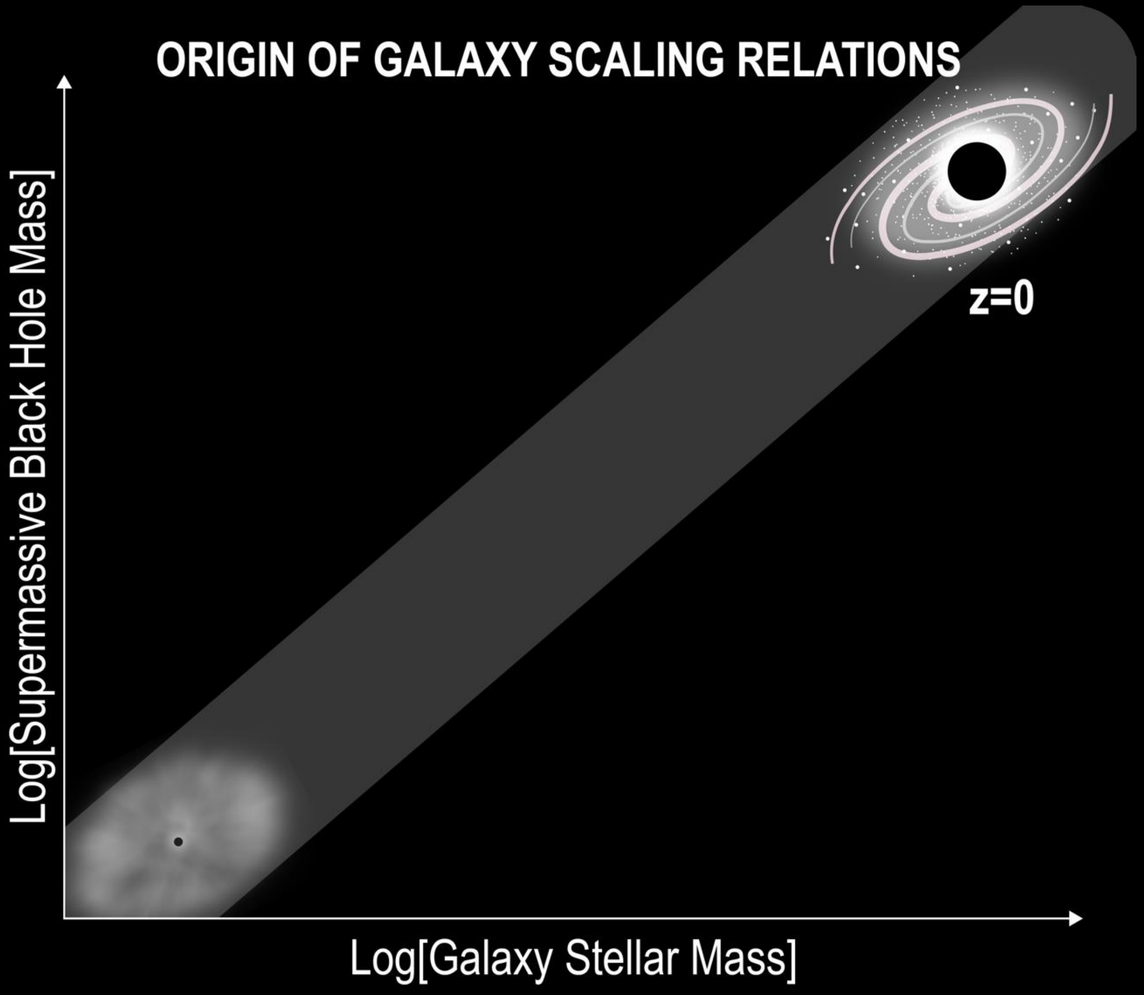
Linking exoplanet atmospheric abundances to their disk origins: Do protoplanetary disks, at radii where most planets form, have non-solar carbon and oxygen abundances?

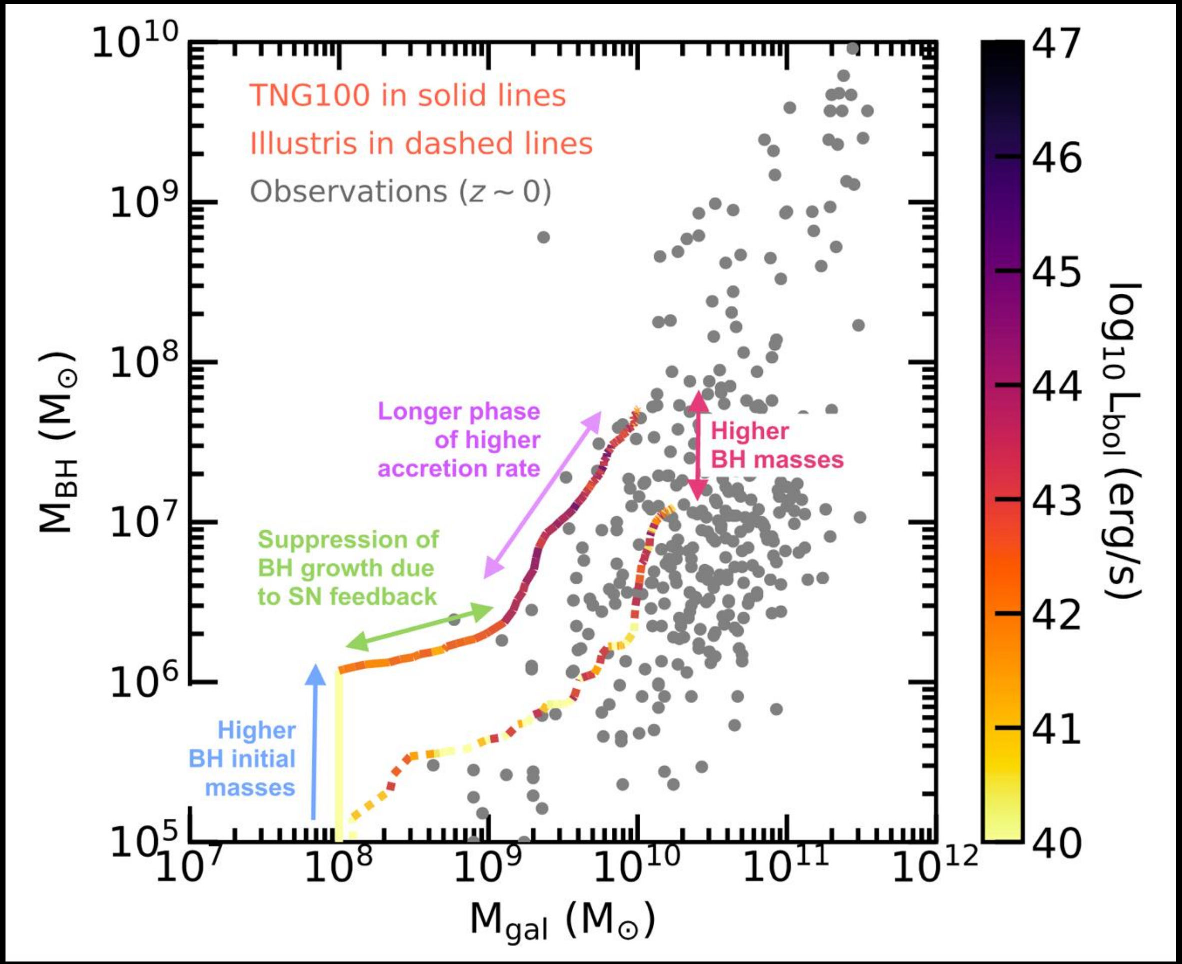


PRIMA's disk survey simulated as two sub-samples with expected error bars.

- H_2 mass derived from HD (112 μm), temperatures from existing ALMA CO or CI
- Oxygen derived from water (PRIMA) and carbon from existing CO ALMA observations
- 200 disks of various ages

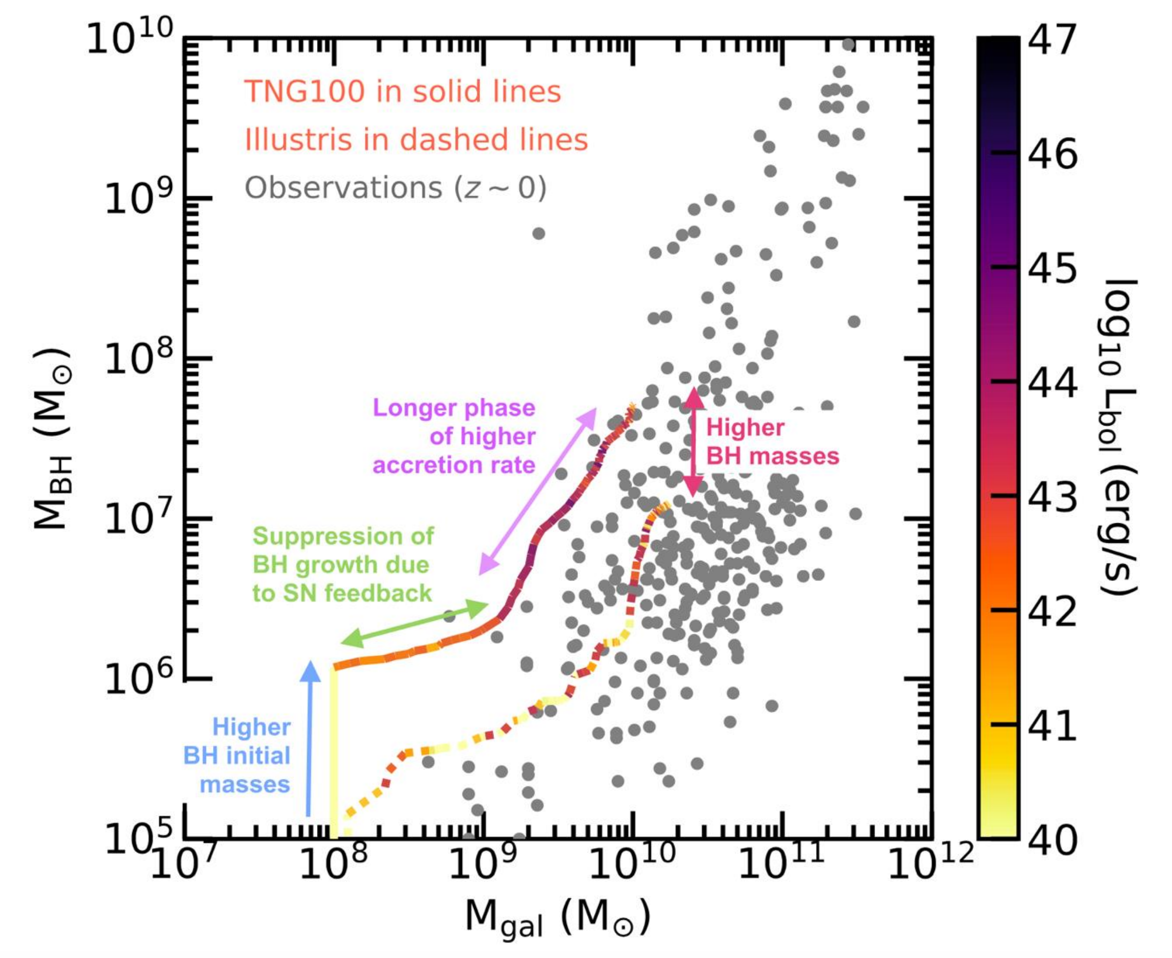
How do supermassive black holes and their host galaxies coevolve?

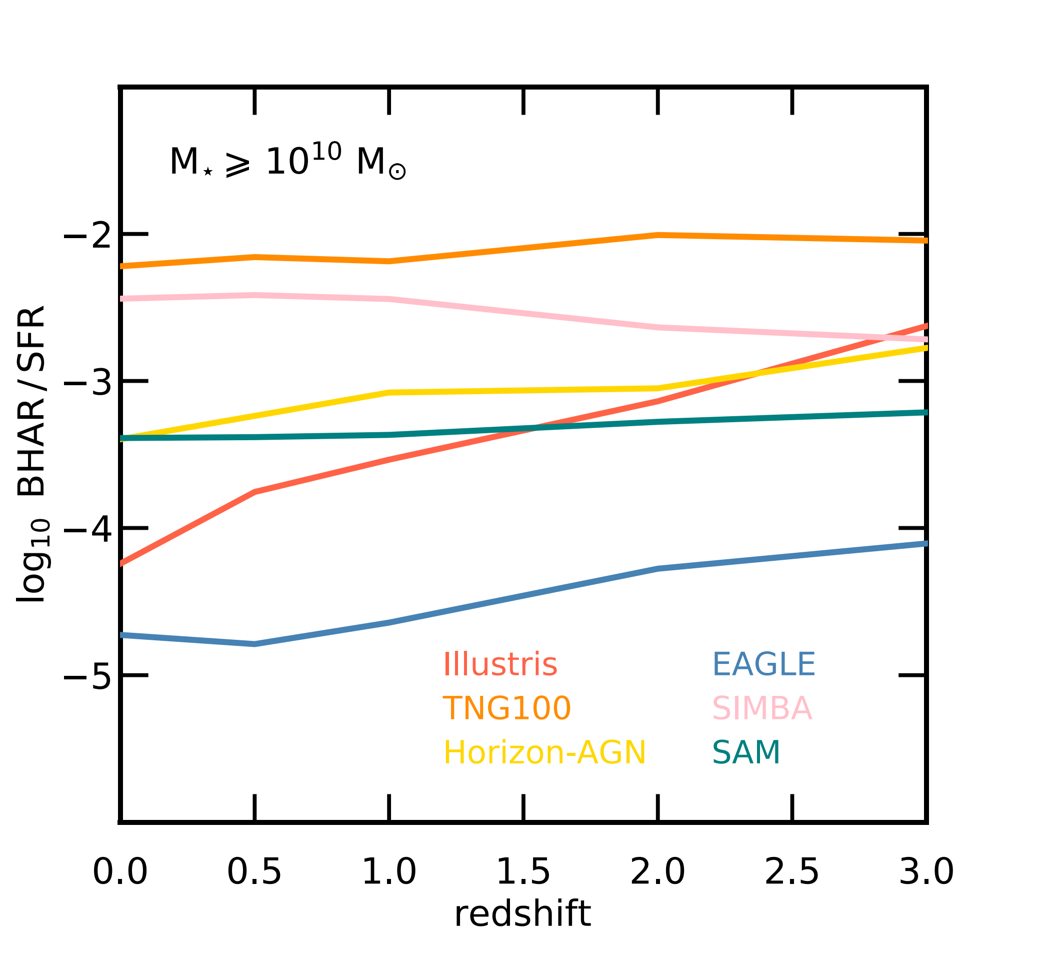




Habouzit+2021a

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

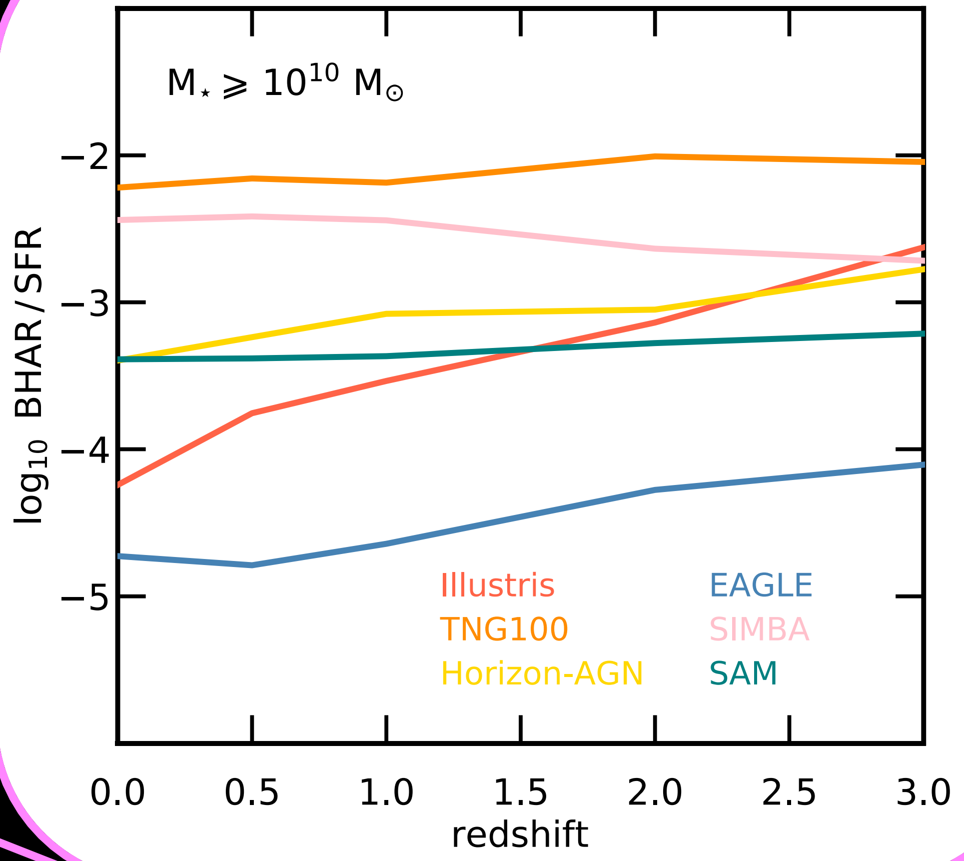




Habouzit+2021ab

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

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

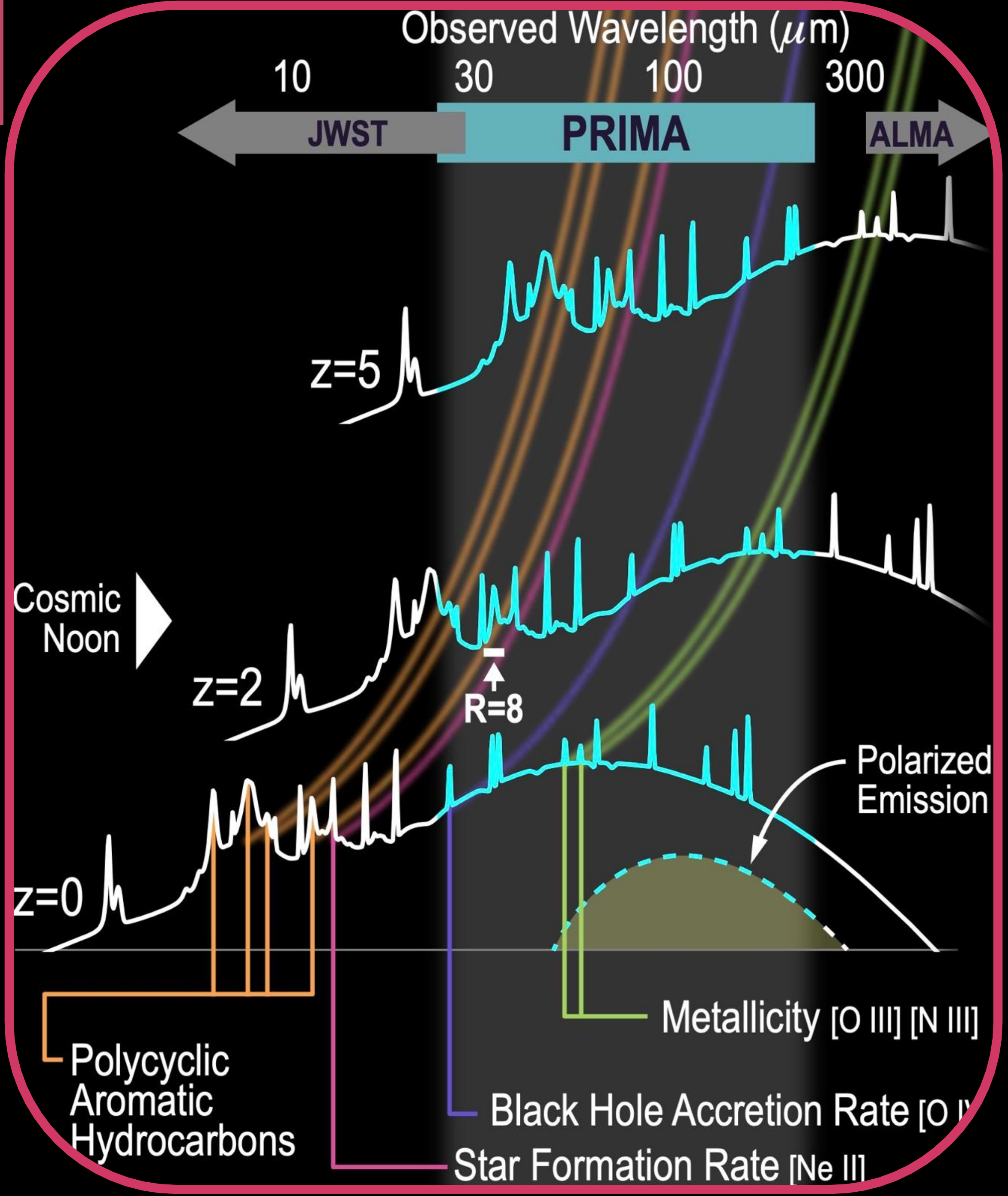


Habouzit+2021ab

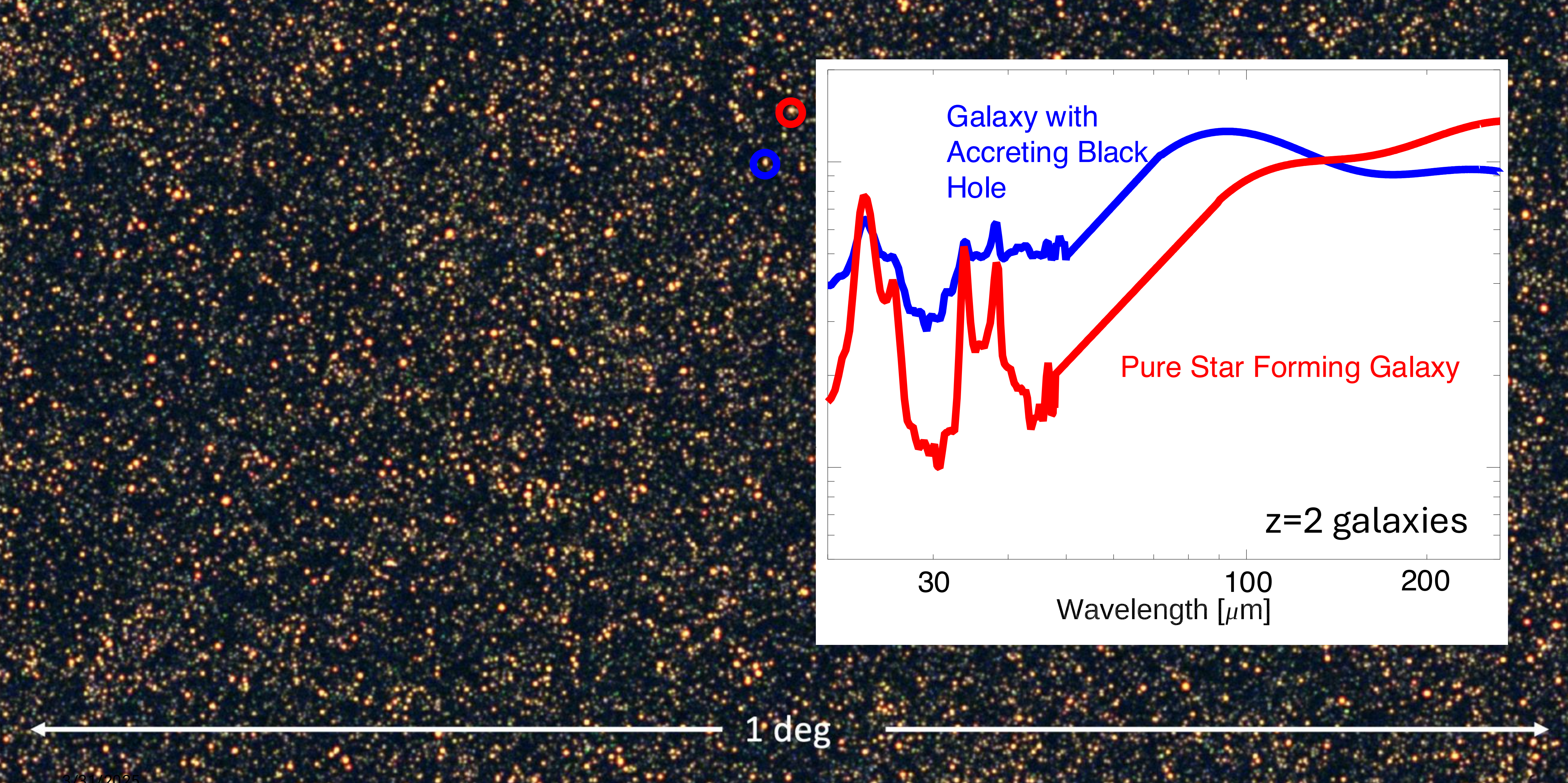
Mid-infrared spectra provide unique signatures of:

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

which shift into the far-IR with redshift

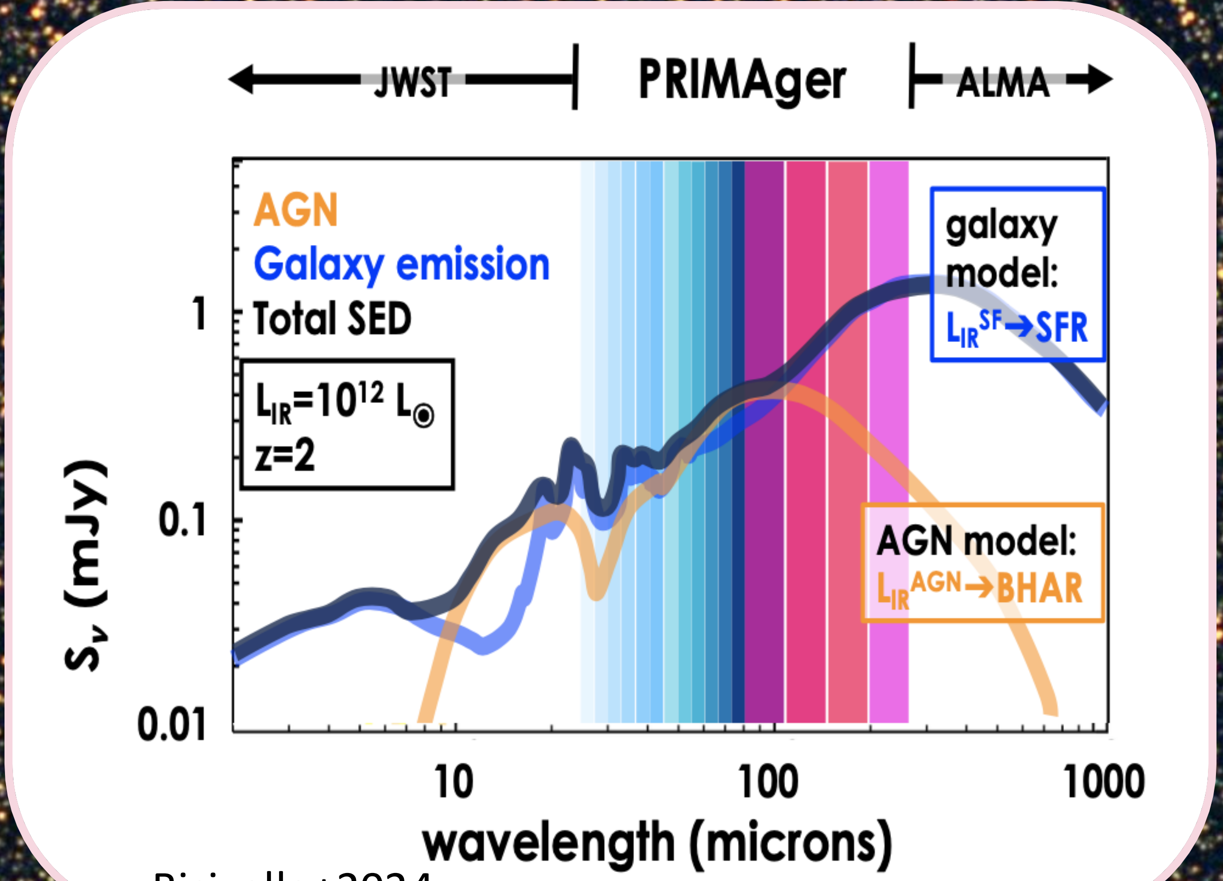


3D Hyperspectral surveys: for every galaxy we get a full IR spectral energy distribution



Simulated PRIMAger 3-color image from SIDES (Bethermin+24)

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



Bisigello+2024

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]) 2 galaxies

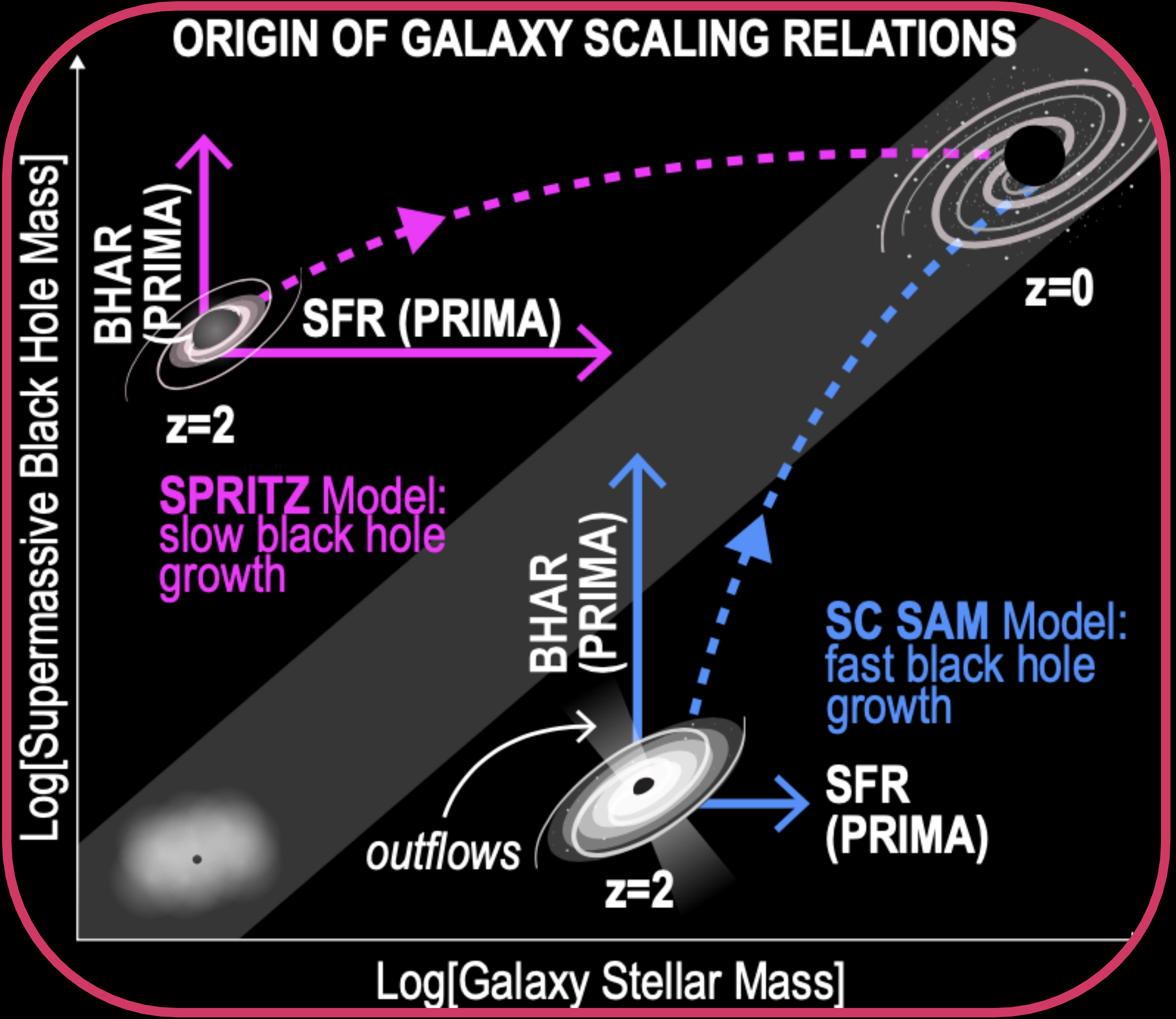
30 200

1 deg

Simulated PRIMAger 3-color image from SIDES (Bethermin+24)

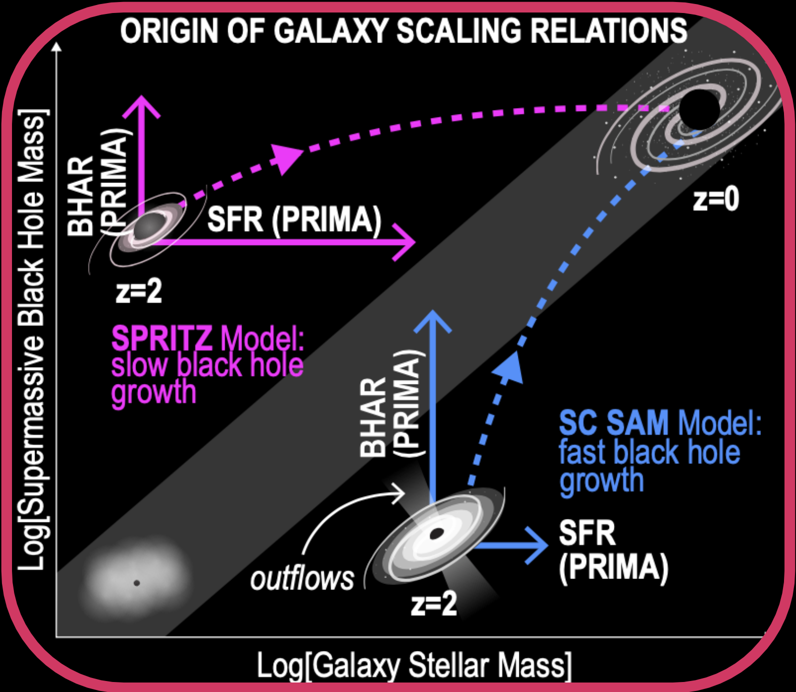
EVOLUTION OF GALACTIC ECOSYSTEMS

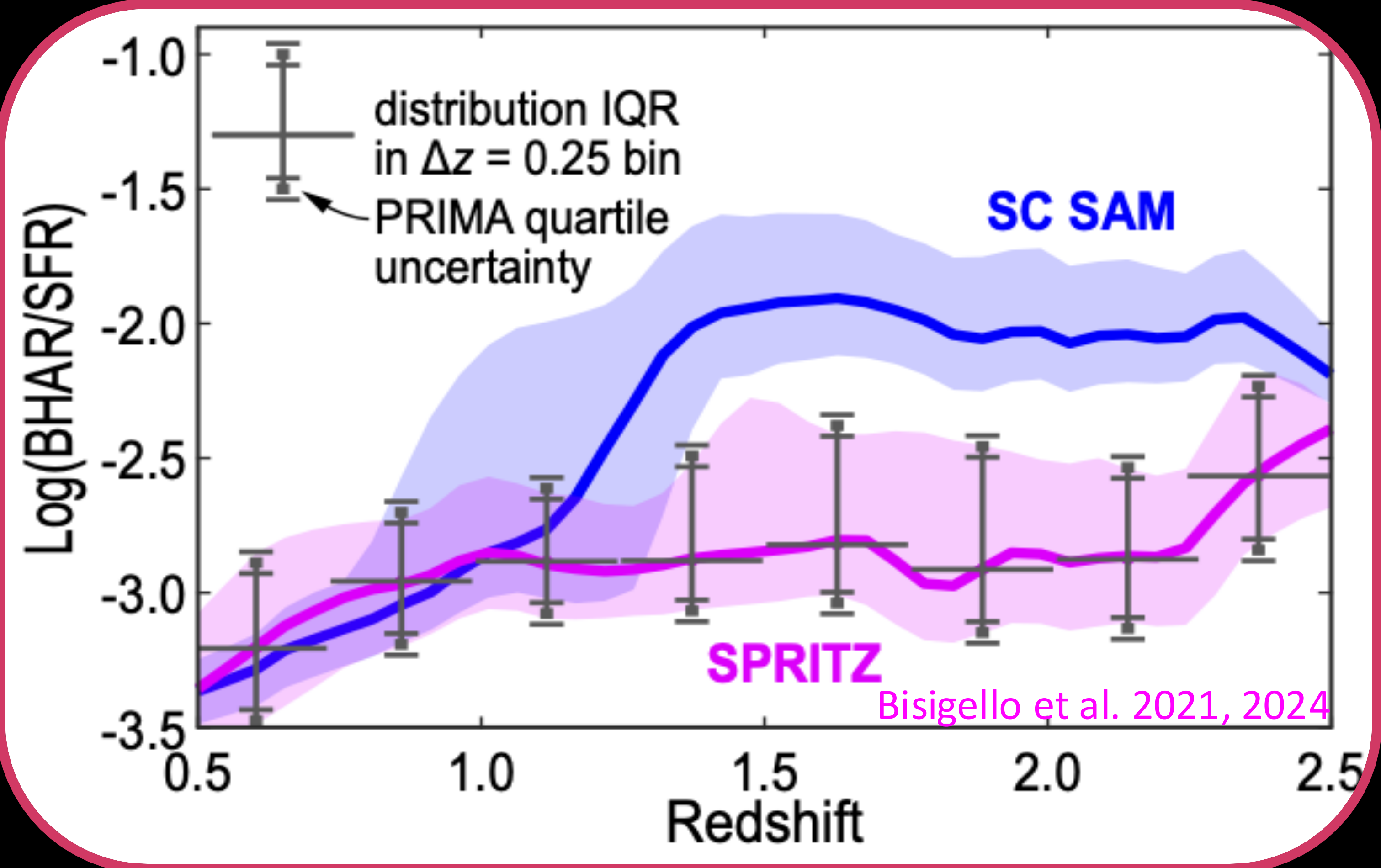
PRIMA will measure the black-hole accretion rates and star-formation rates in luminous galaxies since the peak epoch to map their pathway onto the local M_{star}-M_{BH} relation



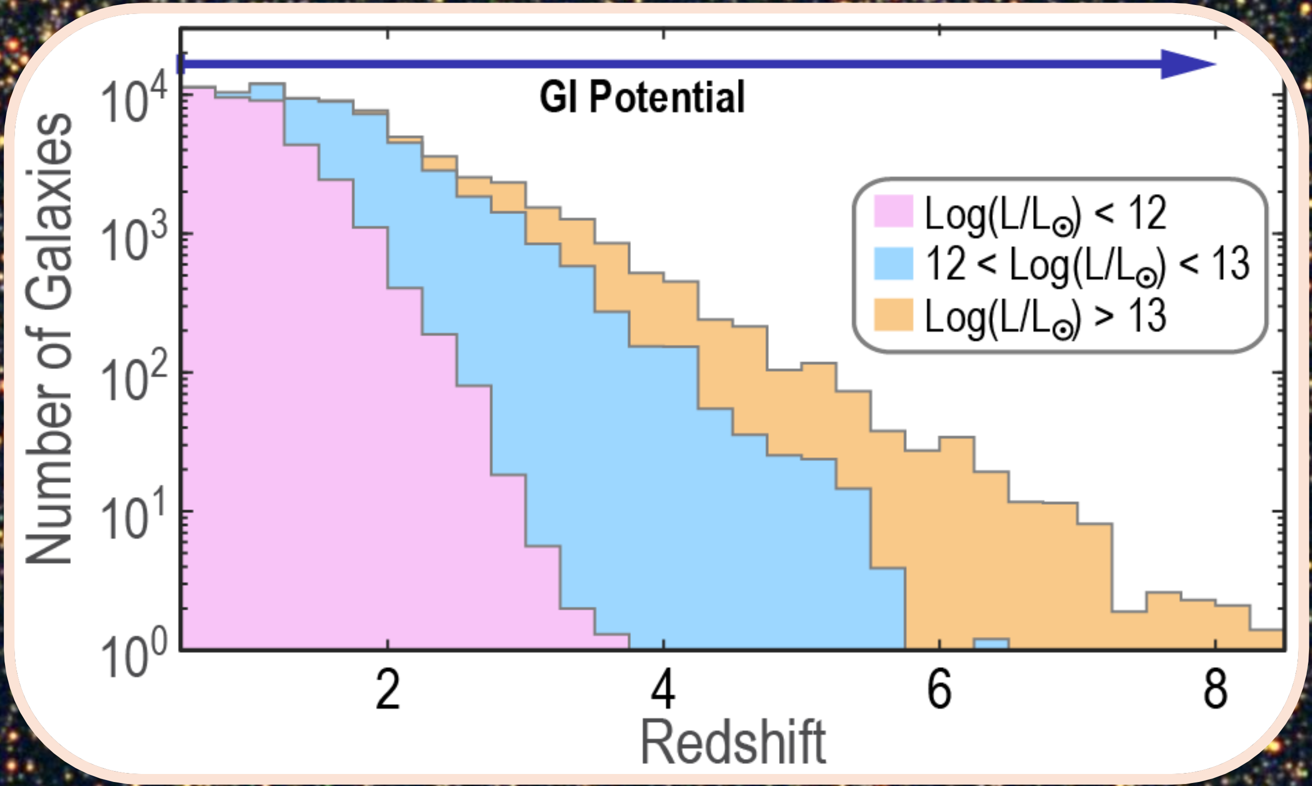
EVOLUTION OF GALACTIC ECOSYSTEMS

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



1 deg

Deep and wide PRIMAger surveys (1 sq. deg + 10 sq. deg) will yield full IR SEDs for ~60,000 galaxies down to L*

-> tons of GI science

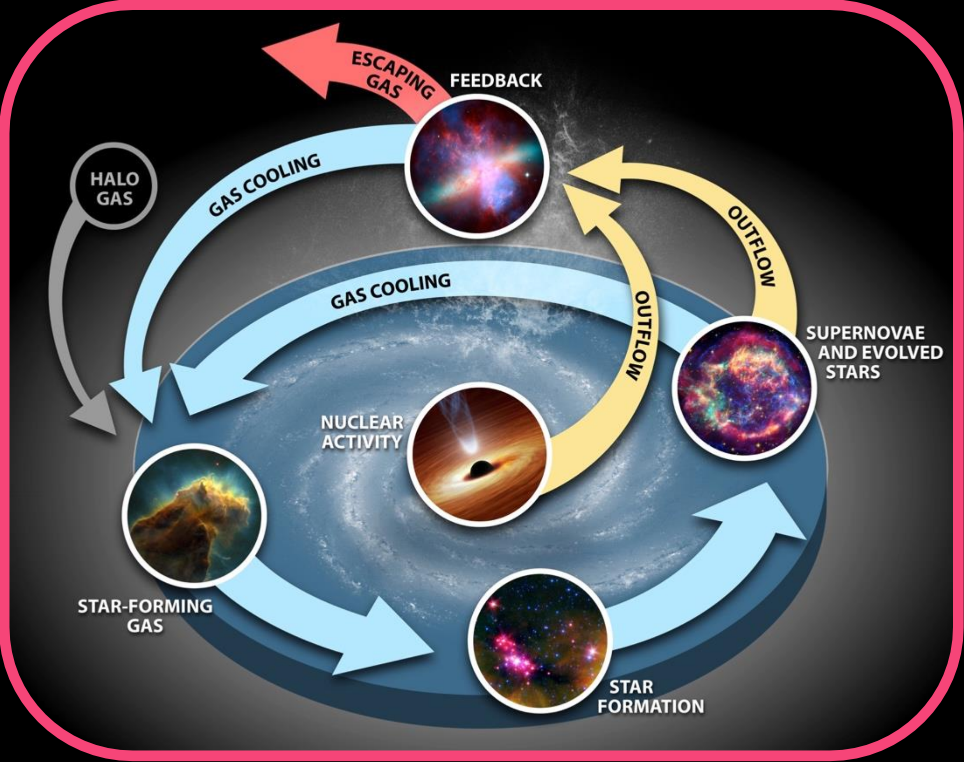
*See **Tiffany Kataria**'s talk on PRIMA GO/GI science later today*

*See talks by **James Donnellan** and **Longji Bing** on Wednesday about overcoming confusion in these deep surveys*

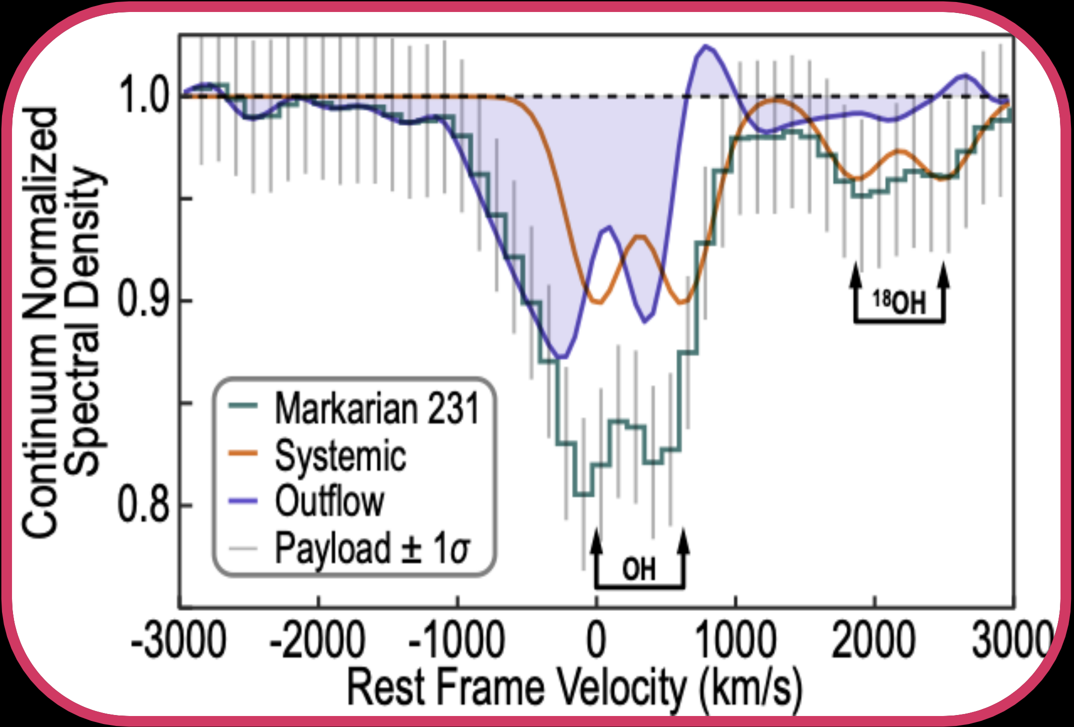
Simulated PRIMAger 3-color image from SIDES (Bethermin+24)

EVOLUTION OF GALACTIC ECOSYSTEMS

What is the role of outflows?



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



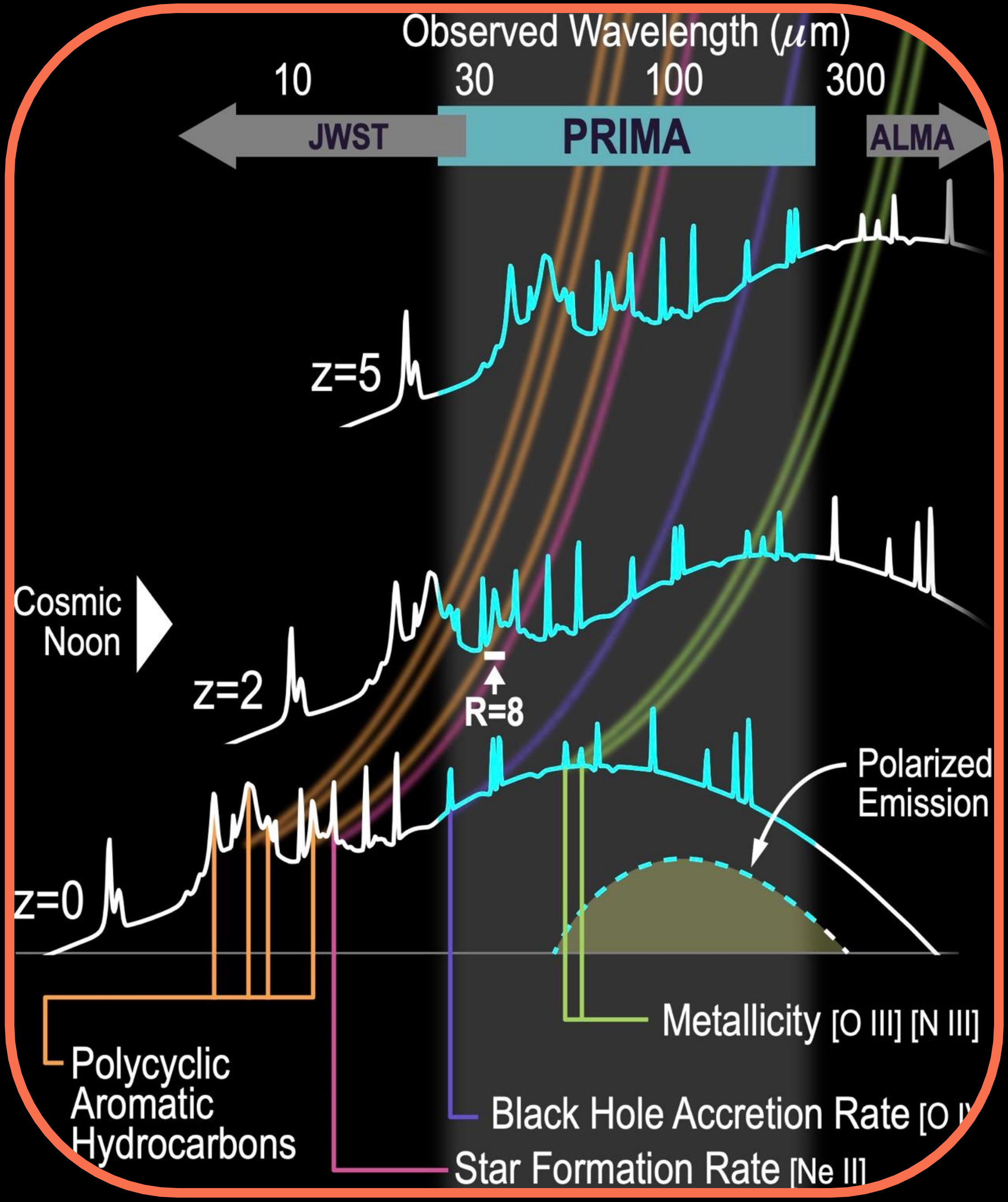
PRIMA/FIRESS high res: OH doublet absorption features (here 84 μm @ z=1.5; also 61, 71, 79 μm)

-> measure outflow velocity and mass

BUILDUP OF DUST AND METALS

Mid-infrared spectra provide crucial diagnostics of:

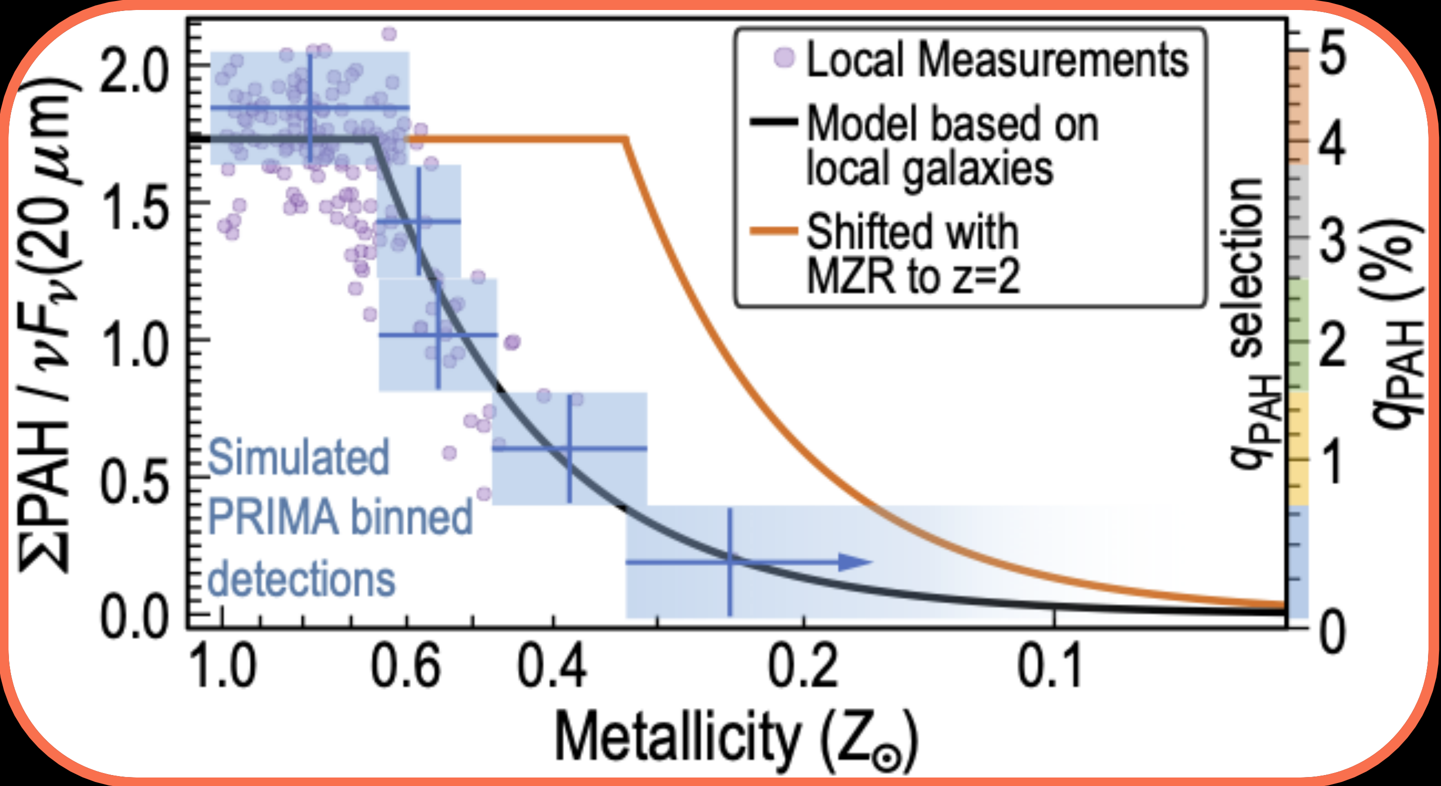
- dust properties (polarized emission)
- metallicity (FIR fine structure lines and PAHs)



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.



PRIMA/FIRESS will observe 100 z=2 galaxies to measure:

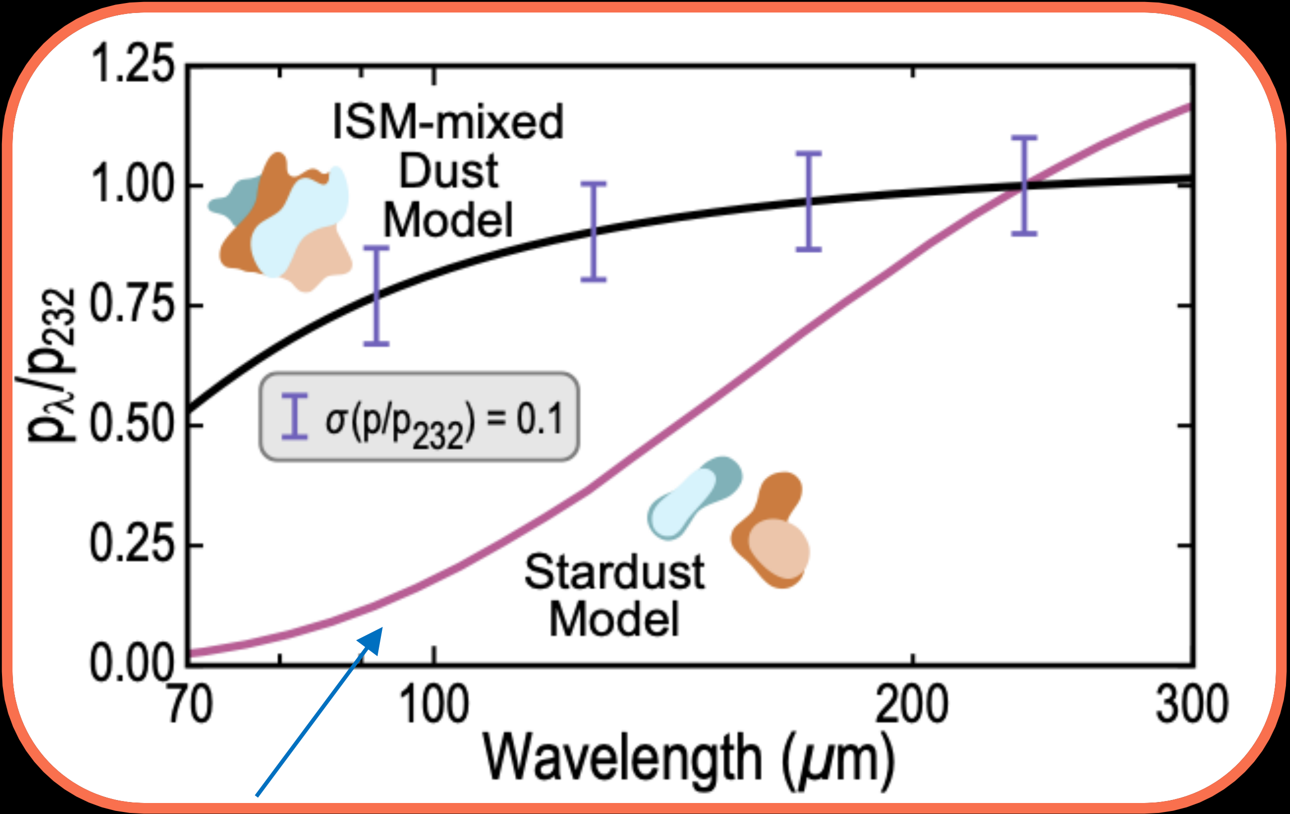
- Gas-phase abundances of O and N via [O III], [NIII]
- q_{PAH} from rest-frame 11.3 and 12.7 μm bands

See Whitcomb et al. 2024

BUILDUP OF DUST AND METALS

Interstellar Dust Grain Growth

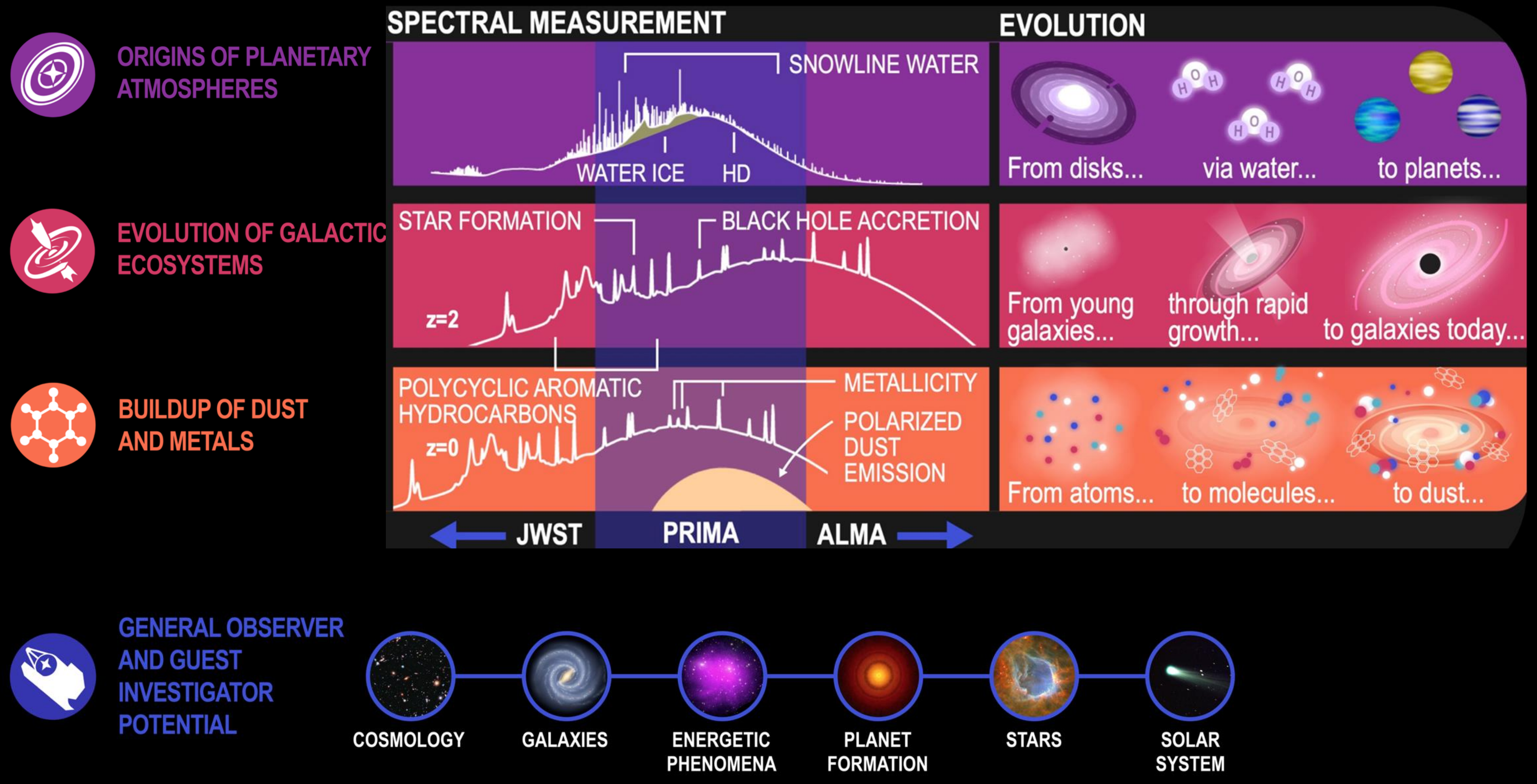
How does the structure of interstellar dust change across environments in the local universe?



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

Learn more

PRIMA webpage:
https://prima.ipac.caltech.edu

Quarterly newsletter (sign up on website)

Monthly talks series P-CAST
(4th Monday of the month, 12pm Eastern)

*See **Tiffany Kataria**'s talk on GO potential and the suite of PRIMA posters at this meeting*

Get Involved

Join a science working group

Develop a science case for the GO Book Vol 2

Attend community events:
PRIMA science meeting Marseilles, Mar 31-Apr 2
PRIMA science meeting Pasadena, May 19-21
PRIMA special session at EAS Ireland, June 26