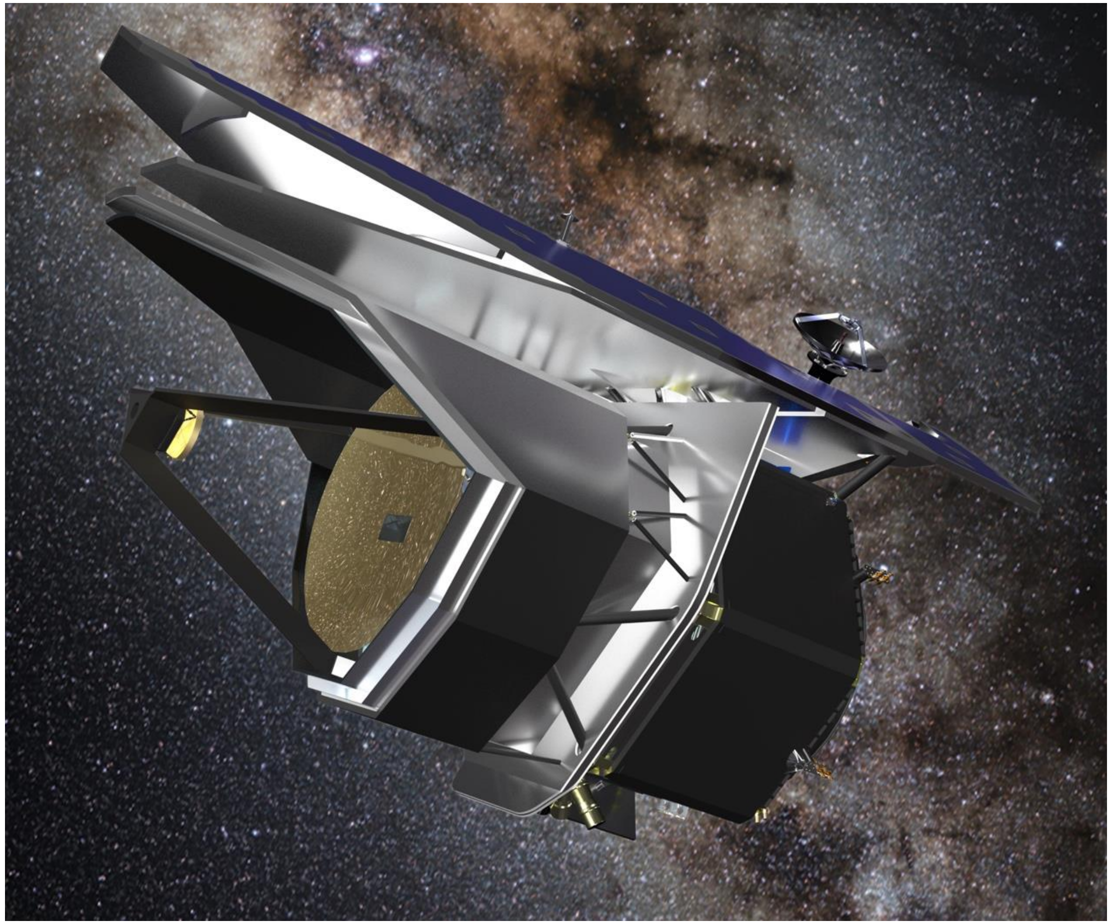
The PRobe far-Infrared Mission for Astrophysics



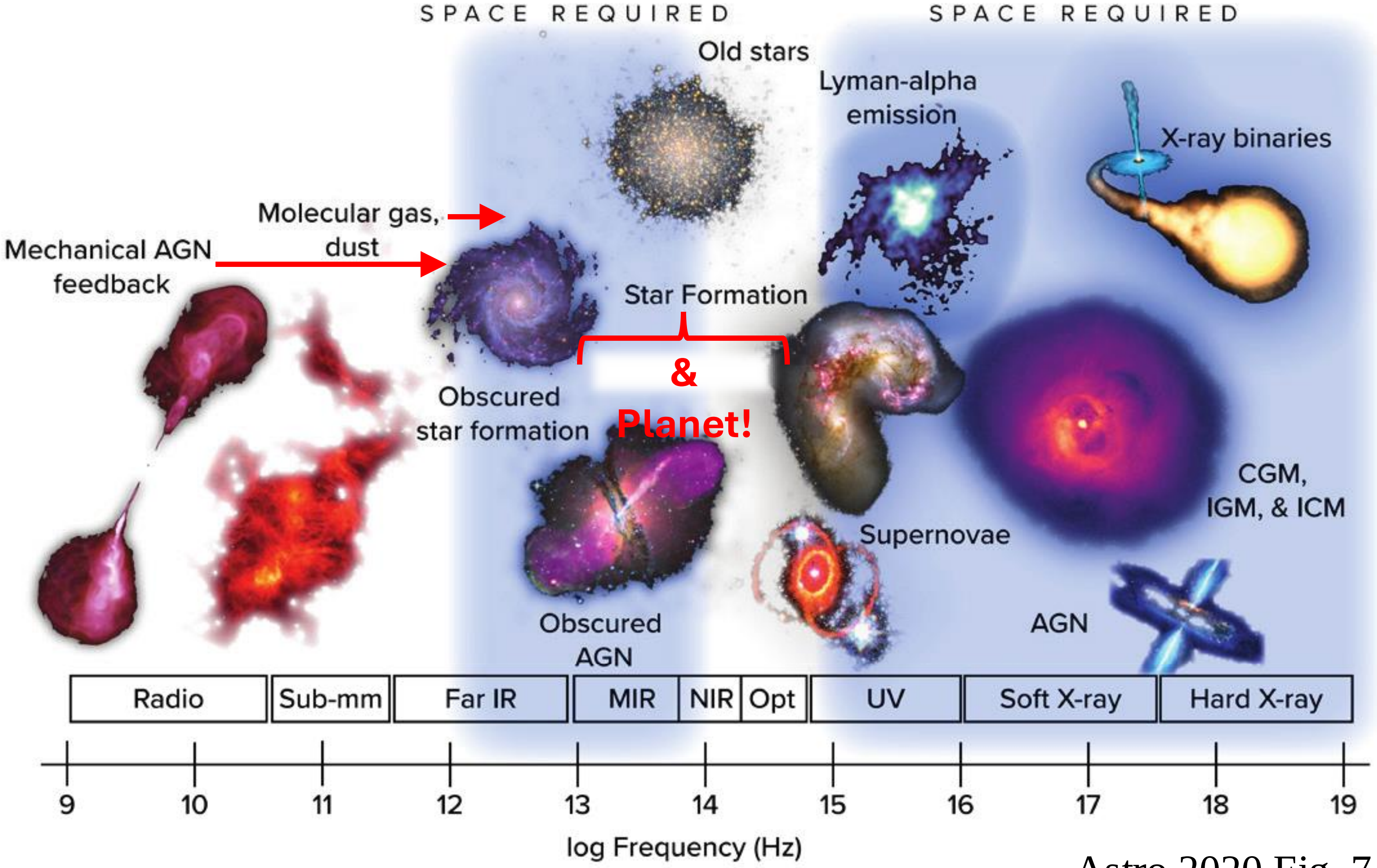
Jason Glenn, Principal Investigator, GSFC
Margaret Meixner, Deputy PI, JPL
Matt Bradford, Project Scientist, JPL
Klaus Pontoppidan, Deputy PI, JPL
Alexandra Pope, Science Lead, UMass
Tiffany Kataria, Deputy SL, JPL
Jenn Rocca, Proposal Capture Lead, JPL

Please see our website for a list of Co-Is:

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

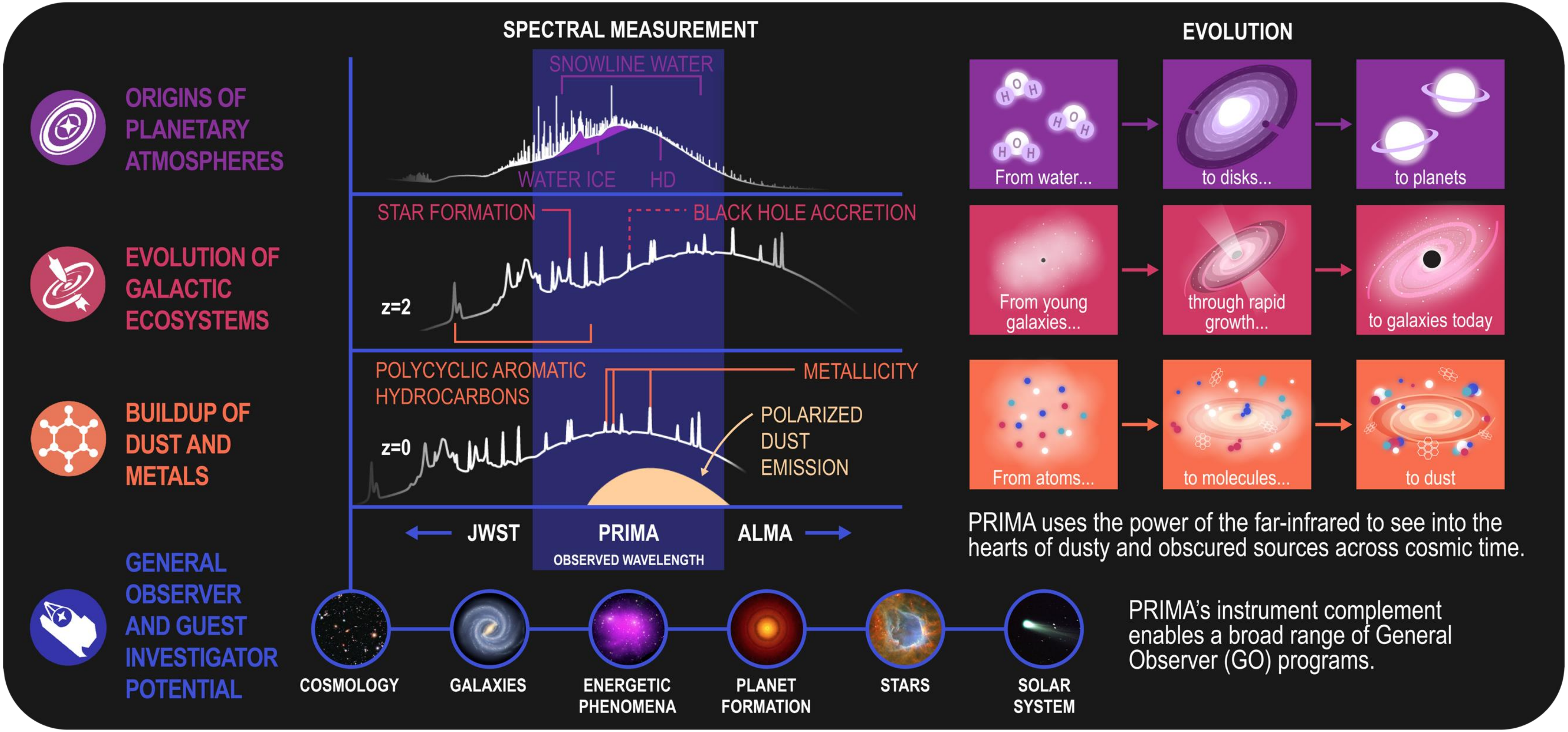
Astrophysics Probed with Far-IR Observations

- Uniqueness: Dust-obscured star formation *and* AGN; protoplanetary disk masses & chemical abundances
- Complementarity: Cooler gas than JWST can access (e.g., < 150 K H_2O in protoplanetary disks)



Astro 2020 Fig. 7.1

Discovering how black holes & galaxies evolved together and how planet got their atmospheres

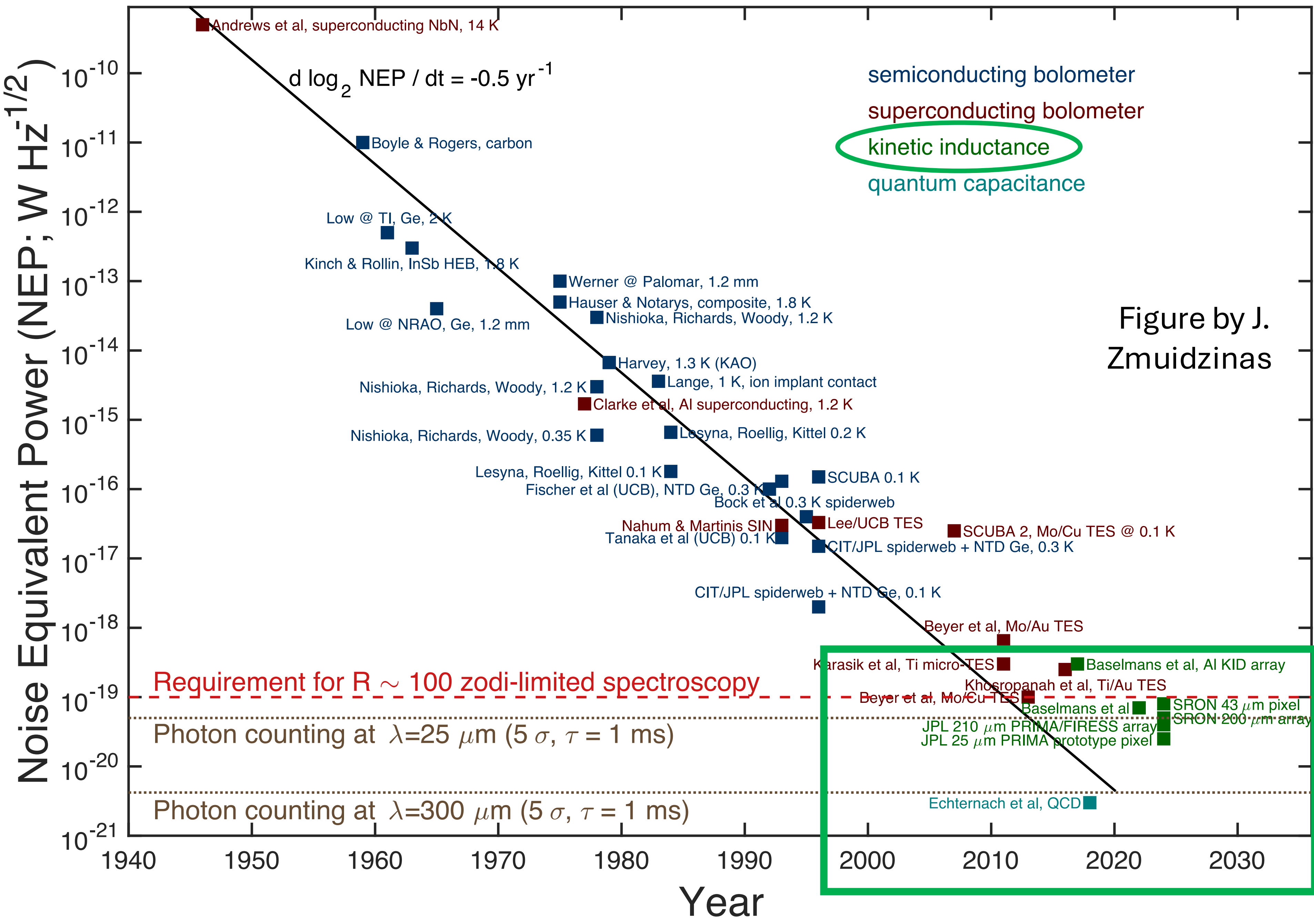


Why Now?

→ Far-IR Detector Technological Readiness

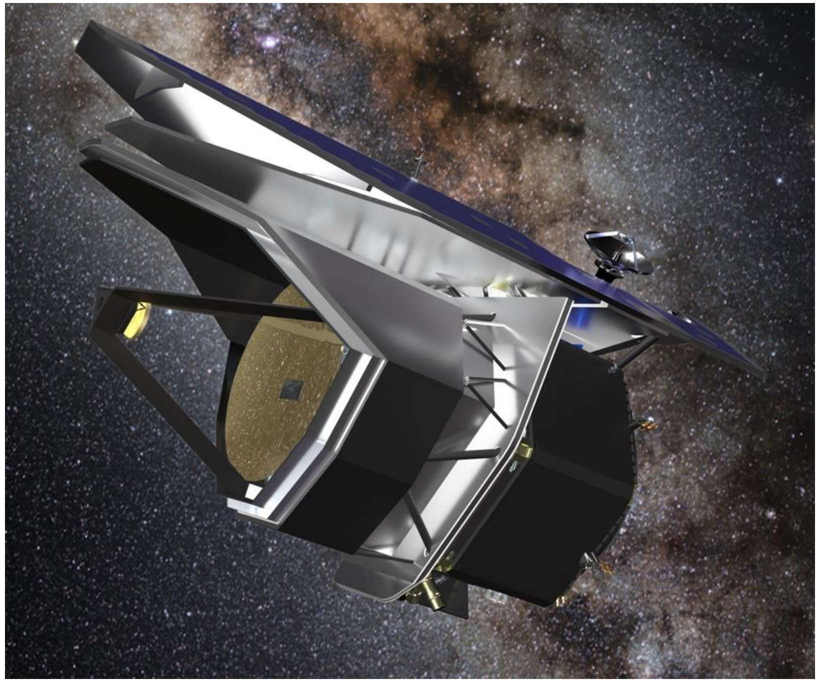
Sensitivities of far-IR detectors have doubled approx. every two years for 75 years!

Probe region of interest



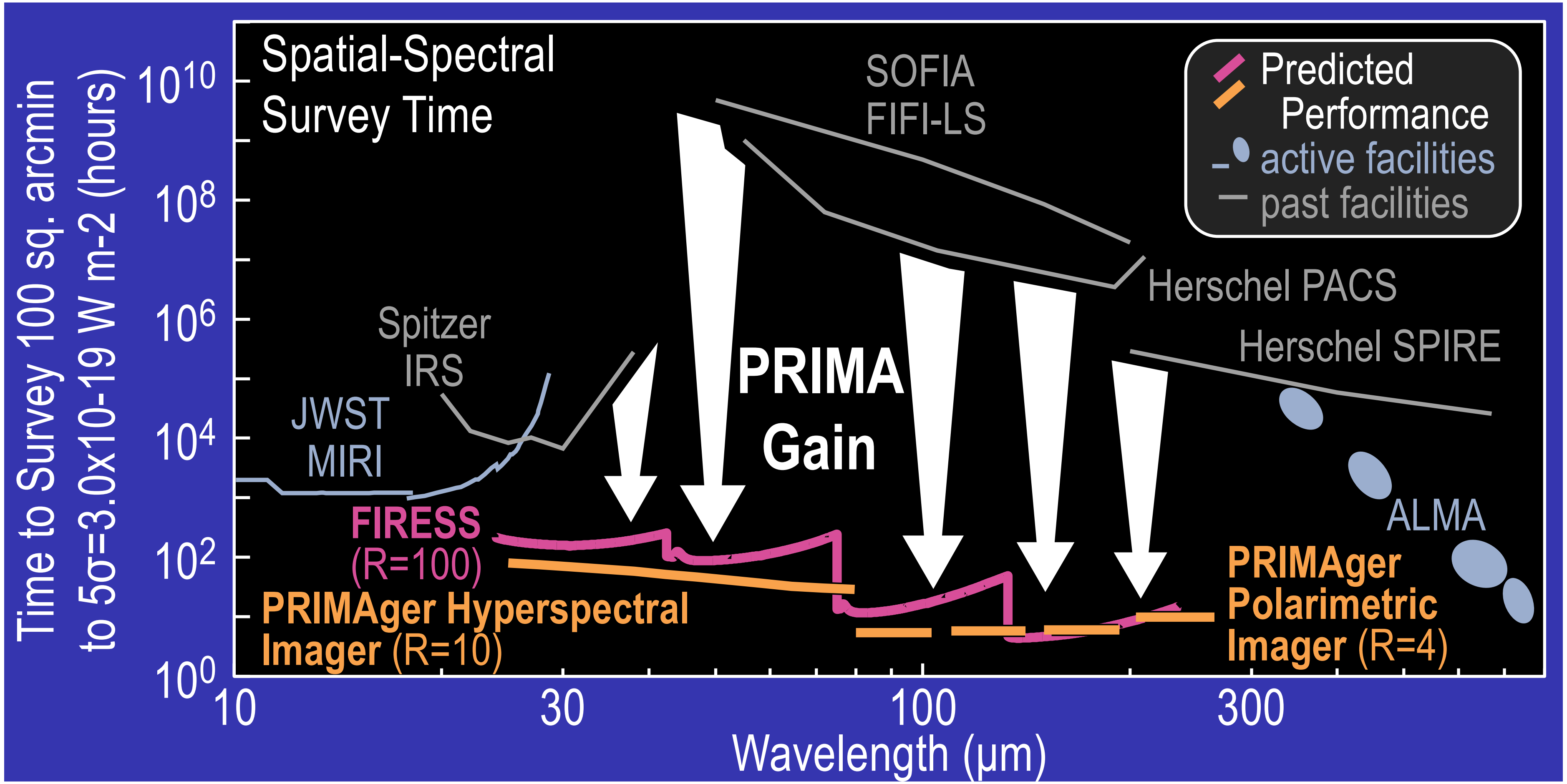
PRIMA

- *25% is for Principal Investigator science*
- *75% of observing time is for Guest Observers*
- *PI data will be available quickly for Guest Investigator science*



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 $(\lambda/112\mu m)^{-1}$
Detectors	100 mK KID arrays (~11k total)
Data	IPAC
Orbit	Earth-Sun L2
Launch	2032
Observations	75% GO, 25% PI (→ GI)

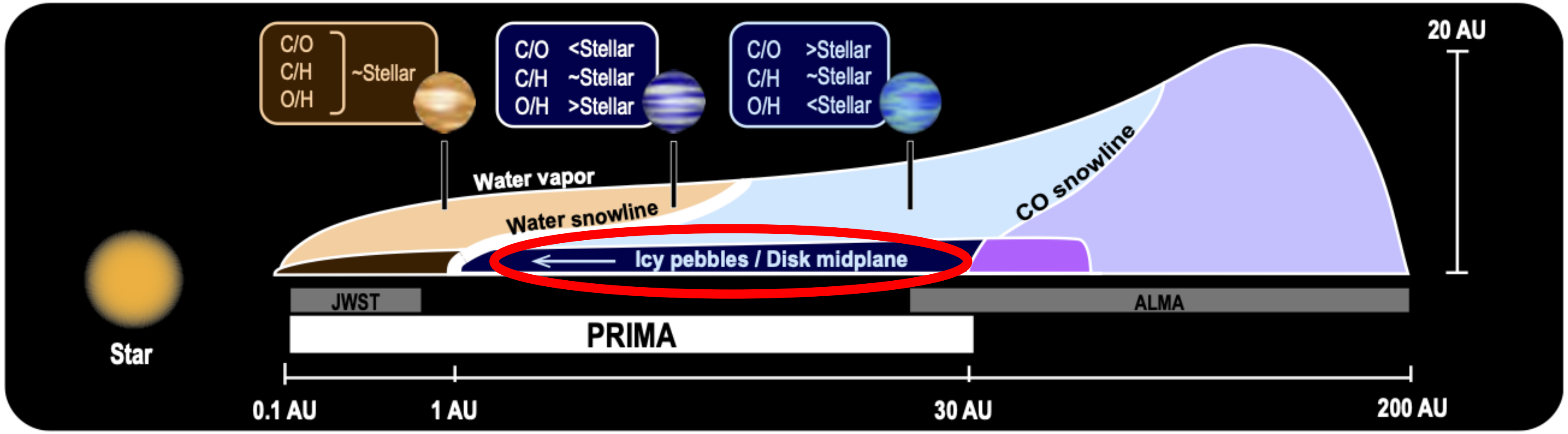
Large Gains and New Capabilities from Sensitive KID Arrays



Newly enabled

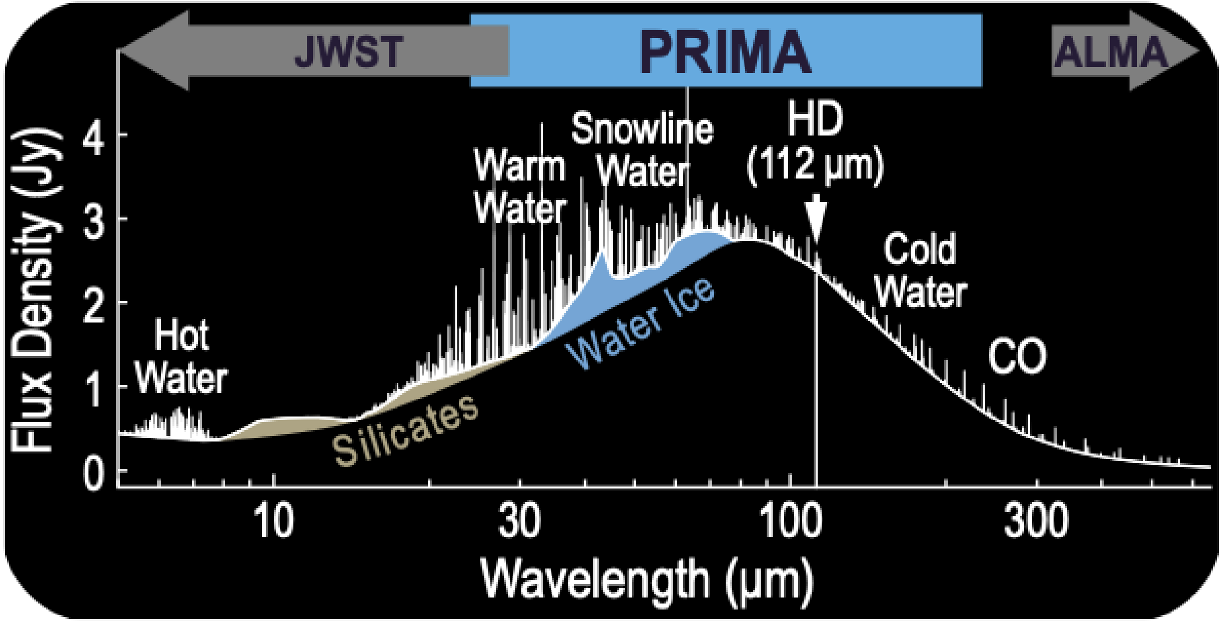
- Extended-source and line intensity spectral mapping
- Extensive polarimetric mapping
- Deep all-sky far-IR survey

Planet Growth in Disks



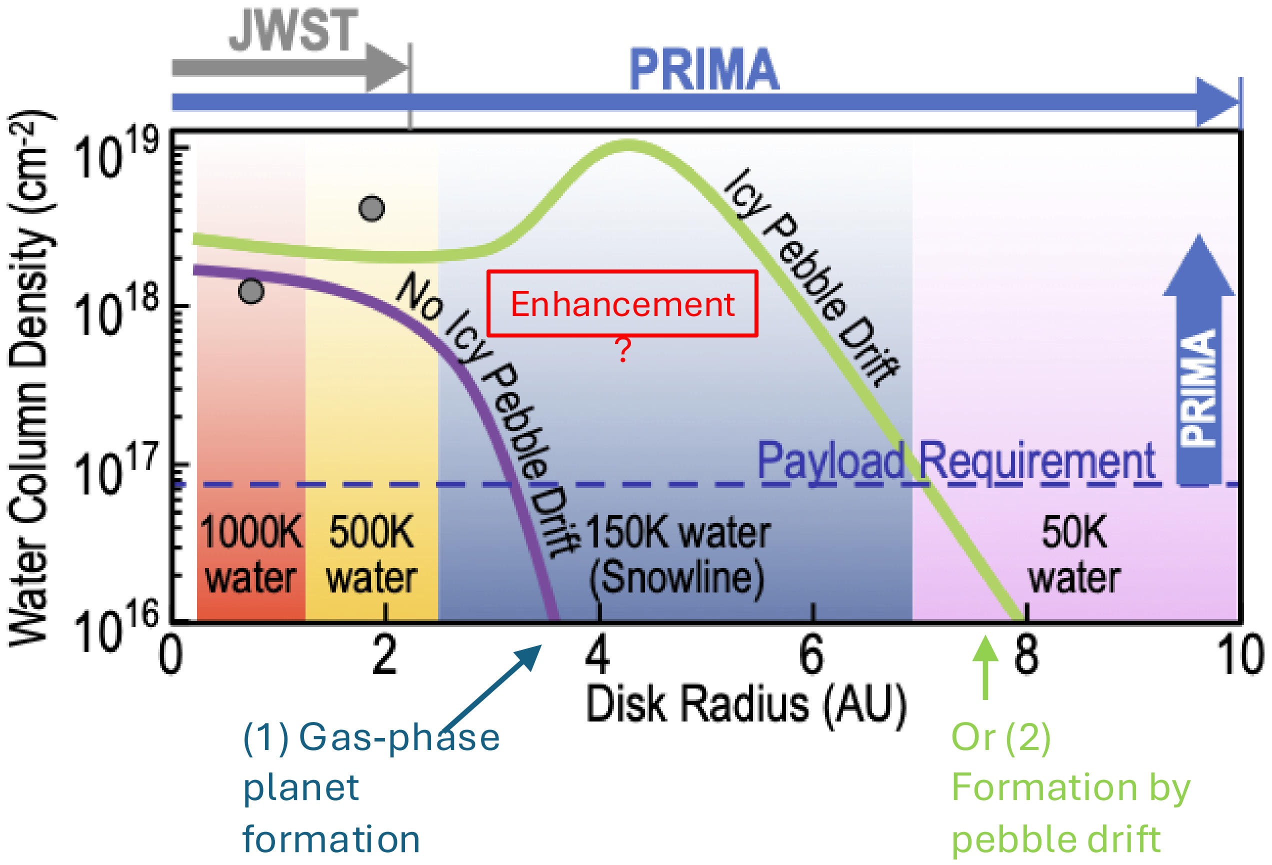
Unknowns and uncertainties

- Disk masses uncertain to an order of magnitude due to CO depletion → HD
- Disk C and O abundances – do they map to stellar metallicities?
- Icy pebbles probably drives planetesimal accretion → water vapor content and distribution

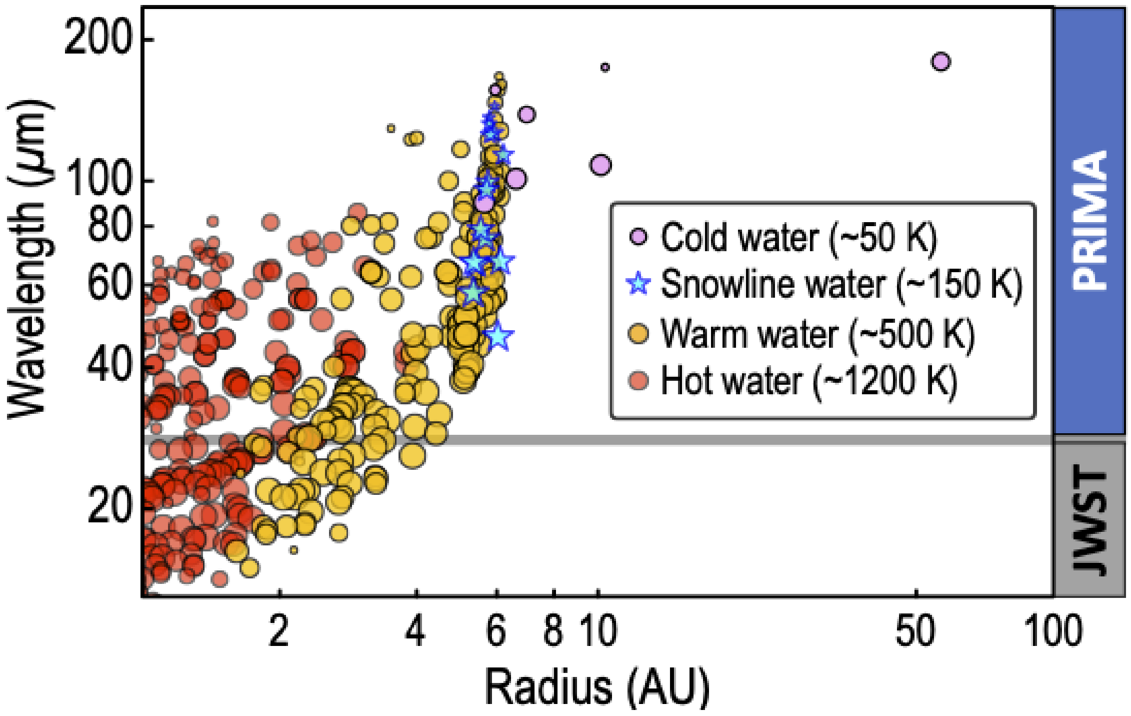


Is there enough water mass to drive the formation of planetesimals near the water snowline?

Water likely dominates the solid disk mass outside the snow line and coagulates via ice pebble drift to form planetesimals. PRIMA measures $N_{H2O}(T)$ to test models.

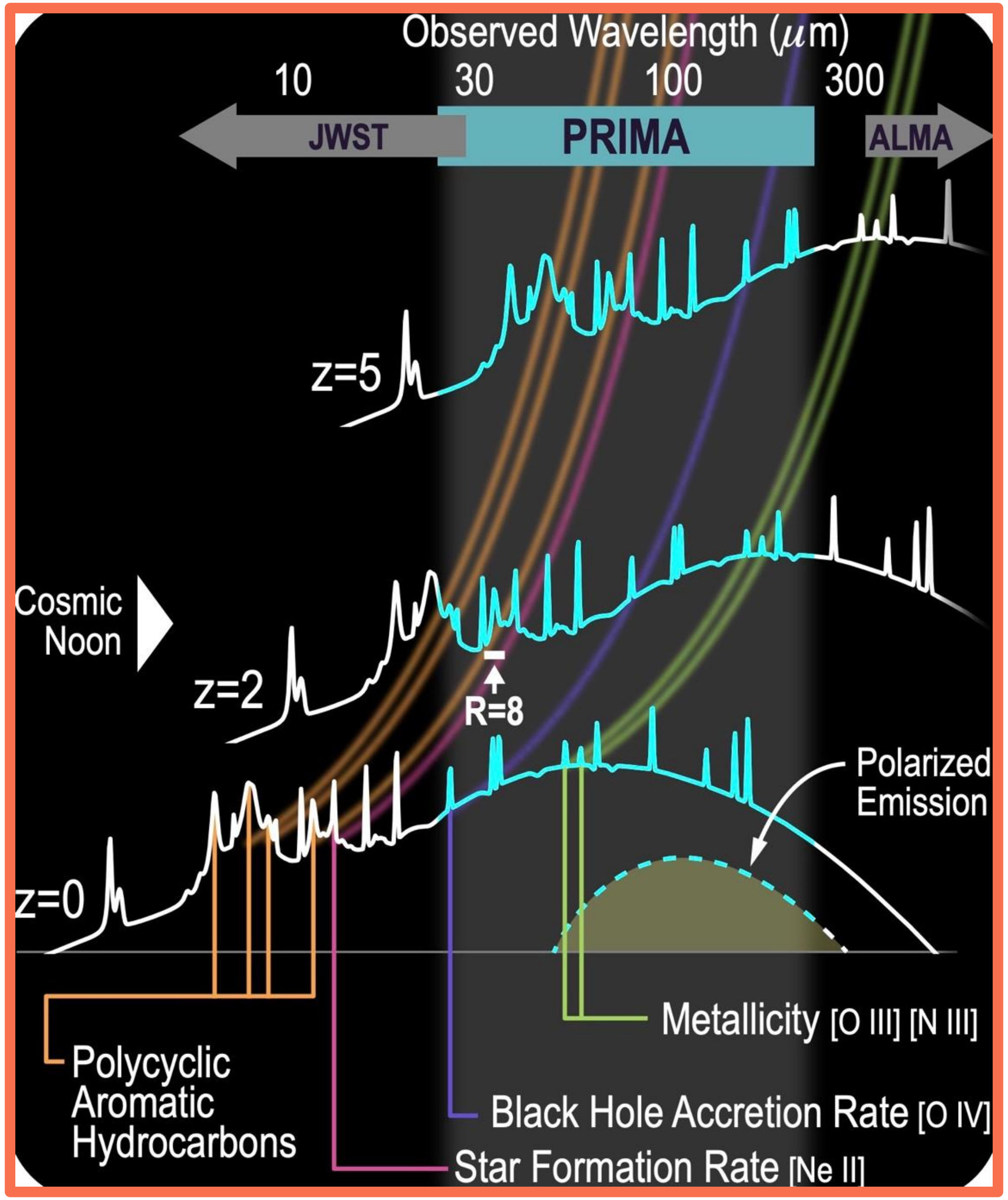


PRIMA FIRESS FTM will measure the level of water enhancement in 200 disks of various ages and masses (point size ∝ line flux).

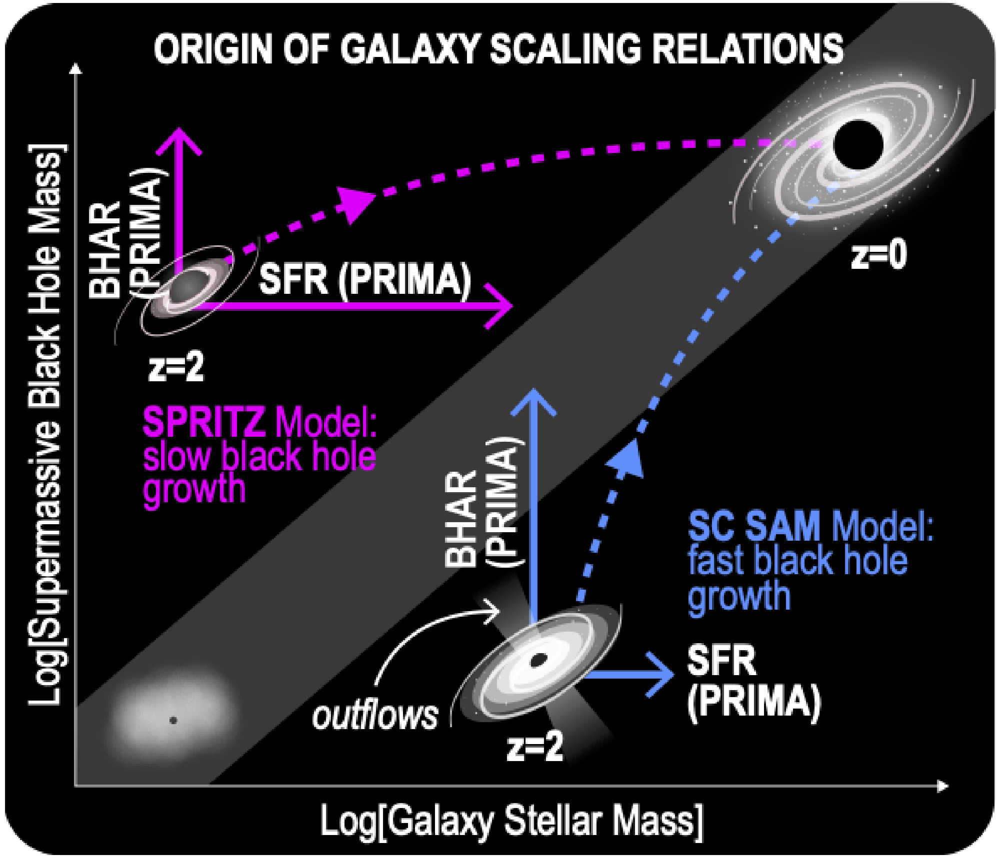


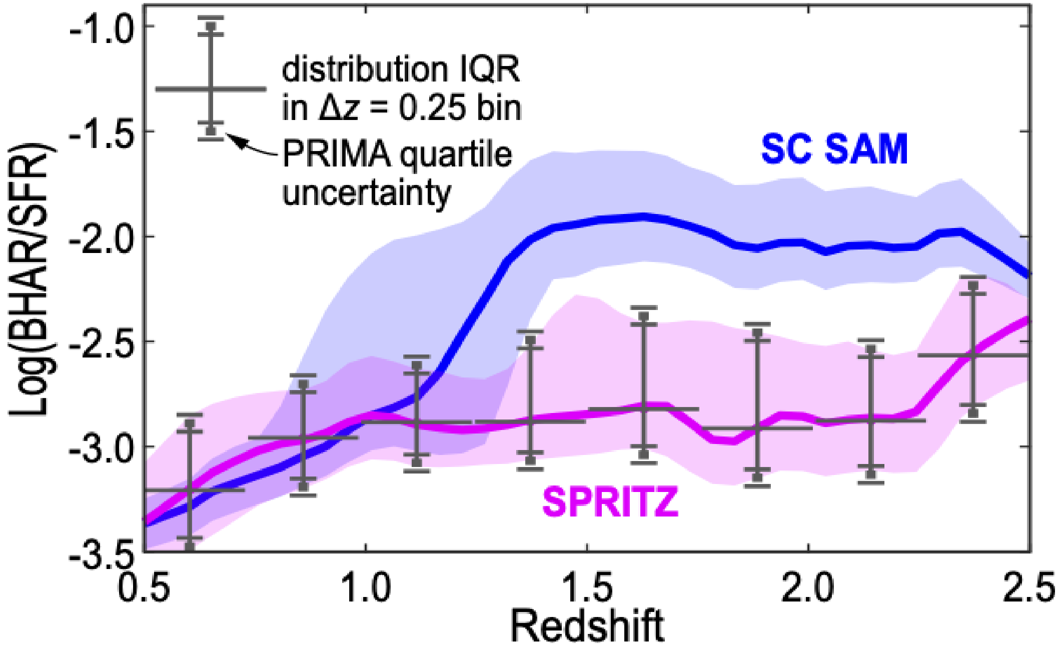
Background: Mid- and Far-IR Galaxy Spectra

- Simultaneous black hole accretion rates and star formation rates
- Metallicities
- PAHs



Galaxy Evolution: What is the relation between black-hole accretion rate and star-formation rate in luminous galaxies since the peak epoch (z ~ 2)?





2 example histories

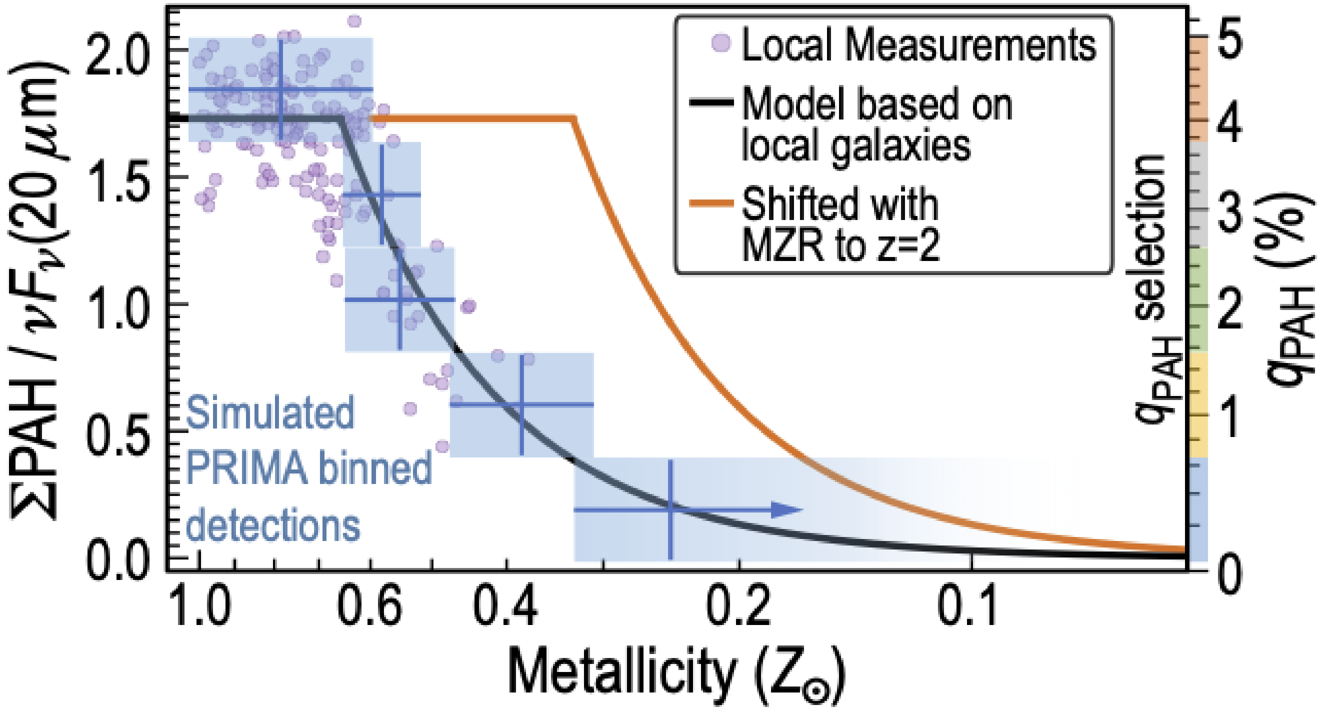
Santa Cruz Semi-analytic model: more black hole growth at cosmic noon.

SPRITZ – star-formation based model linked to Spitzer, Herschel datasets (Bisigello et al. 2021).

- 42k galaxies in 1 sq deg (Donnellan+ 2024)
- Spectroscopic sub-samples of 160 z = 1.0-2.5 galaxies using [O IV] and [Ne II] (rest frame 26 & 12.8 μm)
- Measure cool mass outflow rates of 50 z = 1-2 galaxies with OH (R = 900 @ 84 μm) absorption to test if they are consistent with quenching

The Rise of Dust and Metals: Has the relationship between PAHs and metals evolved since cosmic noon?

In the local universe, there a reduction in PAH emission with reduced metallicity.

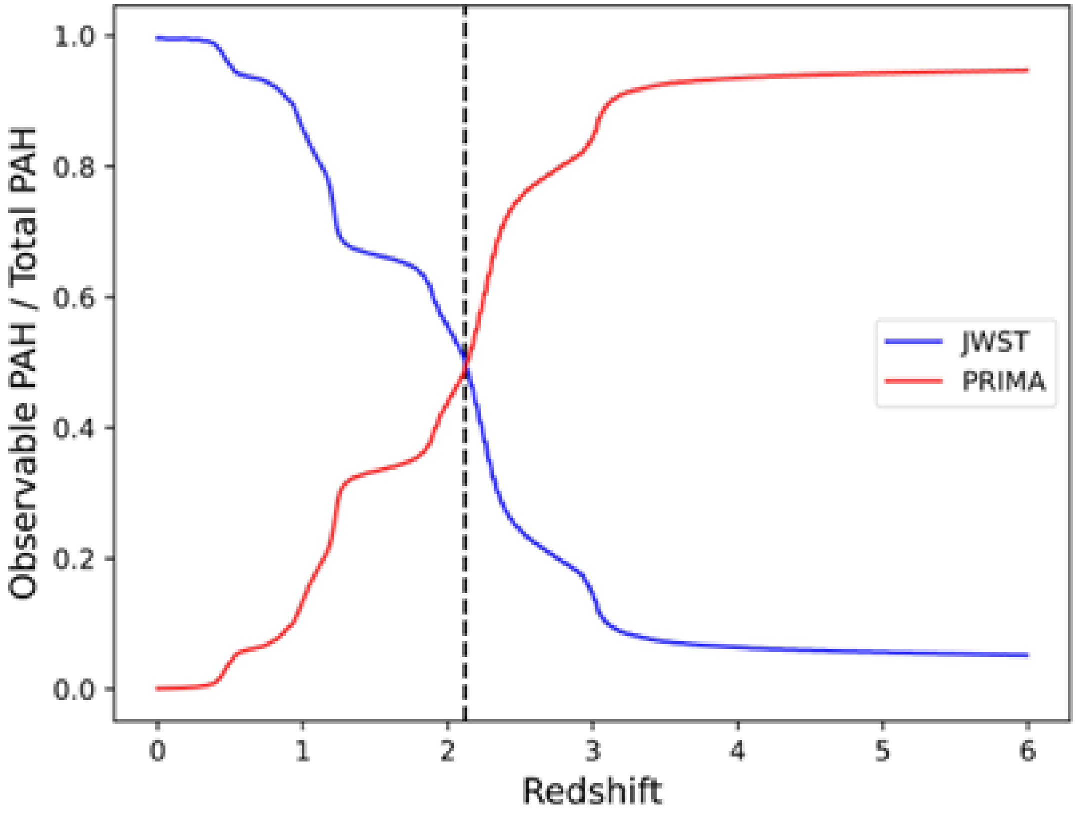


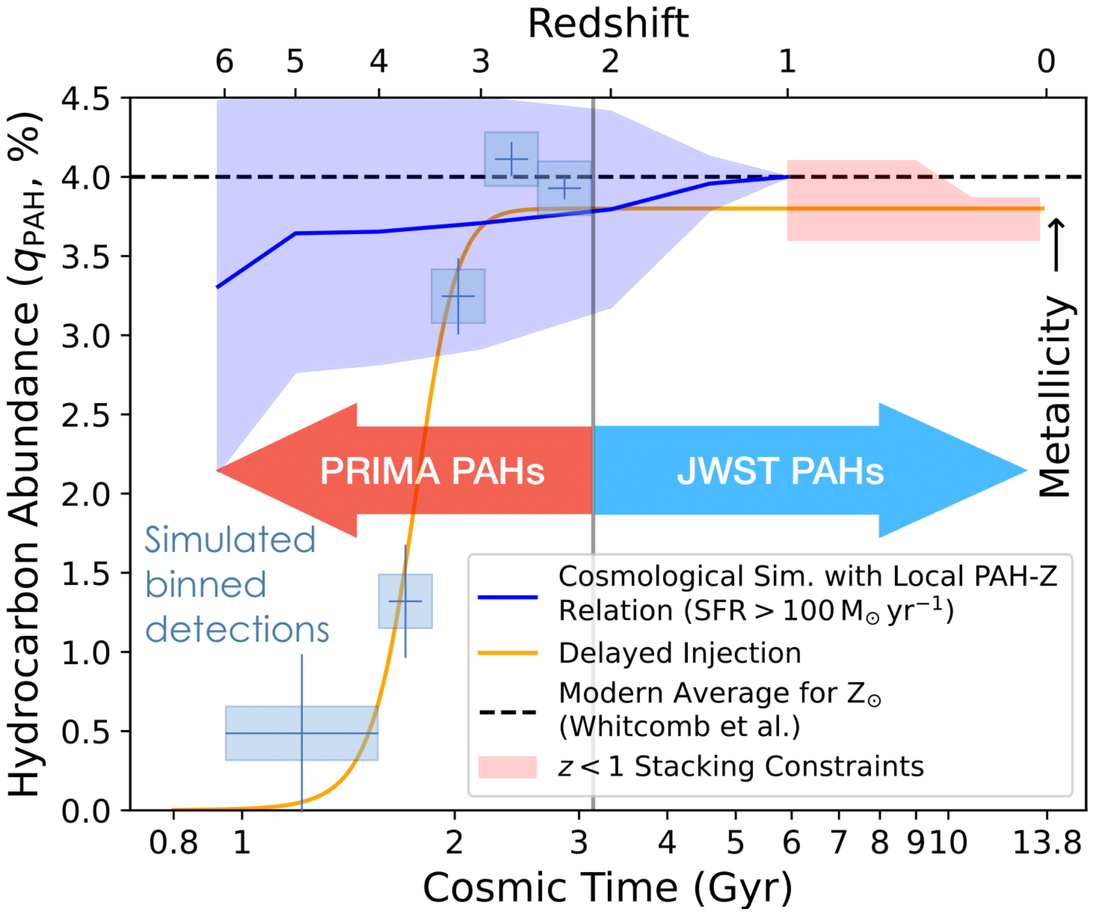
For 100 $1.75 \leq z \leq 2.25$ galaxies in 5 q_{PAH} bins, PRIMA will measure

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

GO Science: High-z PAHs

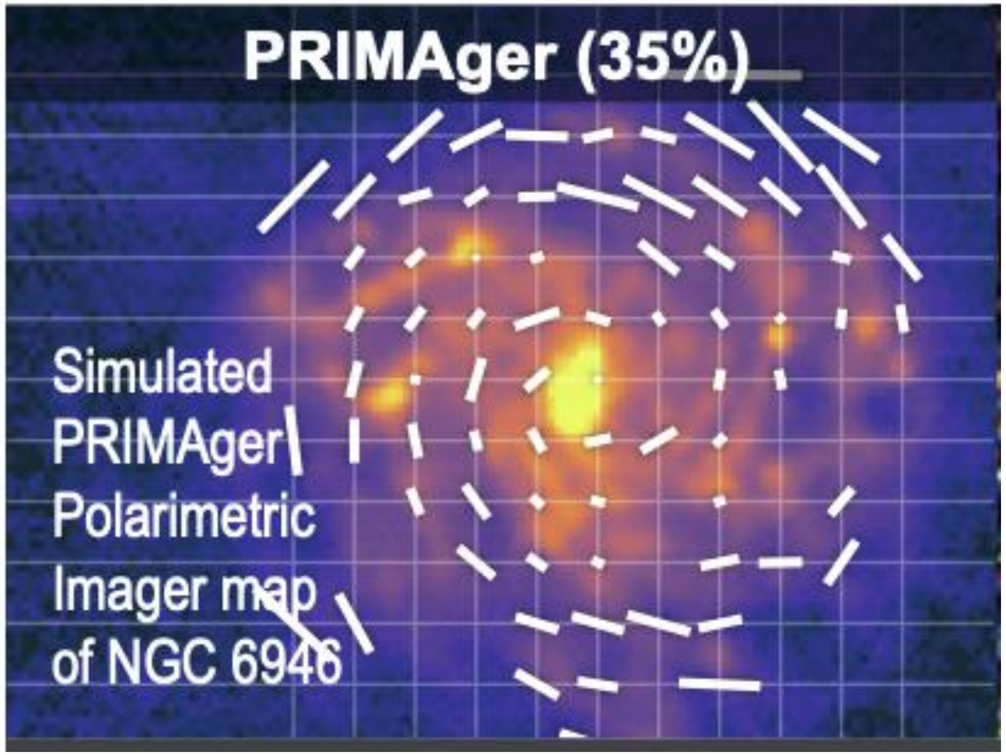
An exciting and unique opportunity to observe hydrocarbons in the early universe, complementary to JWST (Donnelly et al., PRIMA GO Science Book)





GO Science: Polarimetry and Magnetic Fields in Galaxies

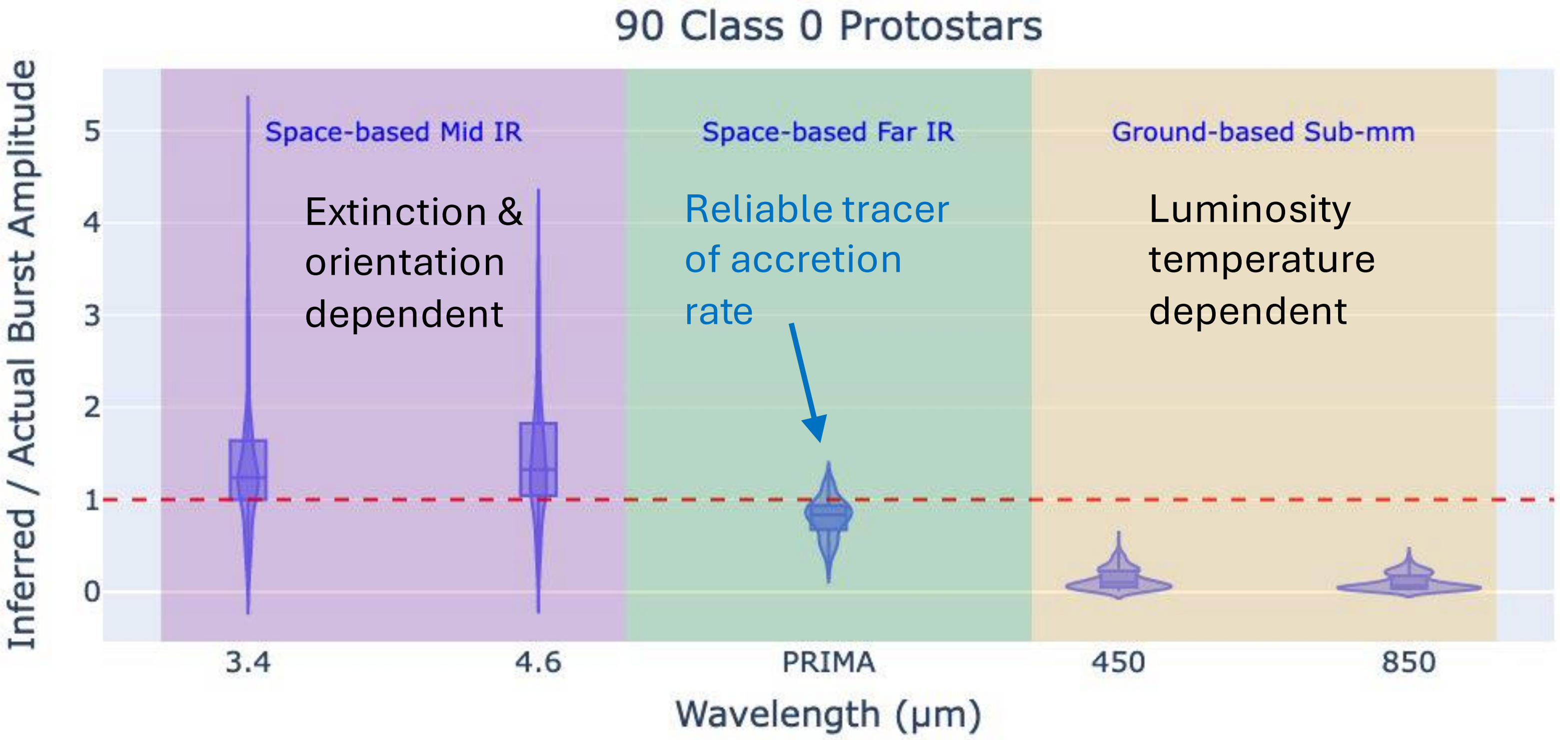
(In PI science, PRIMA will test dust models with far-IR polarimetry.)



- Simulations of polarimetric capability: Dowell+ 2024
- Magnetic fields (Lopez-Rodriguez; Louvet; Paré; Pattle)
  - Galactic clouds: The role of magnetic fields in cloud dynamics
  - Nearby, resolved galaxies: Do molecular cloud fields generally align with and reflect radio (cosmic ray) derived fields on larger scales?

GO Science: How do stars get their mass?

- Mass: *The* fundamental property of stars, but we do not know how they accrete their mass. Quiescent or episodic?
- Far-IR: Only wavelength for which luminosity correlates tightly with accretion rate.
- Test: >50% of mass is derived from rare events?
- Survey: 2000 protostars with cadences of 2 wks to 5 yrs (& back to Herschel)
- Archival value: Huge, plus polarimetry!



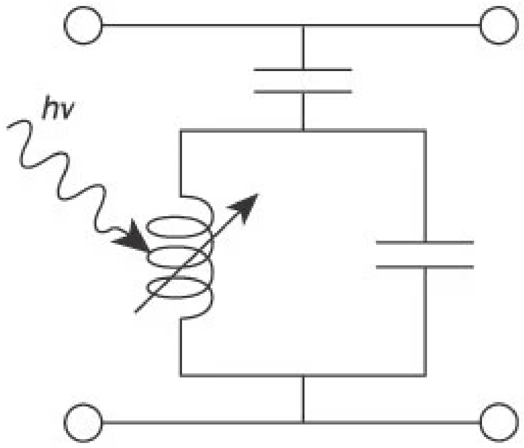
Battersby, et al., (2023, PRIMA GO Science Book)

KID Principle of Operation

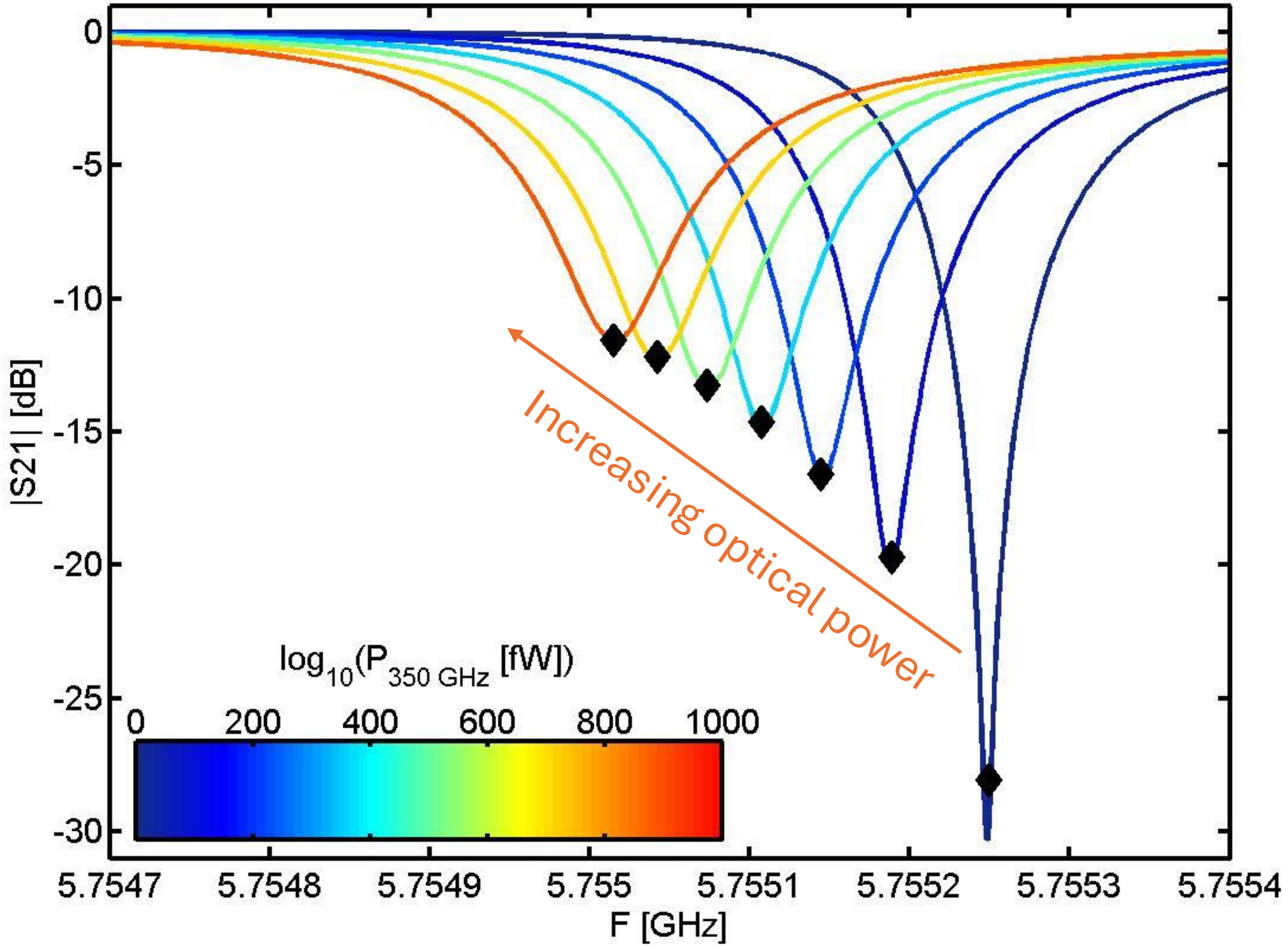
Superconducting resonator

$Q = \frac{f_0}{\Delta f}$ 10^4 to 10^6

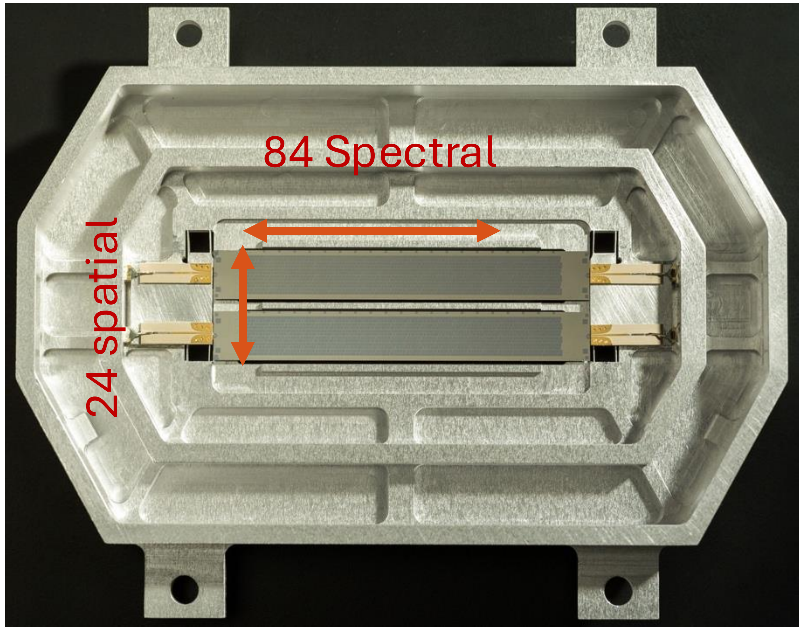
$f_0 = 0.1 – 10$ GHz



Day et al. 2003

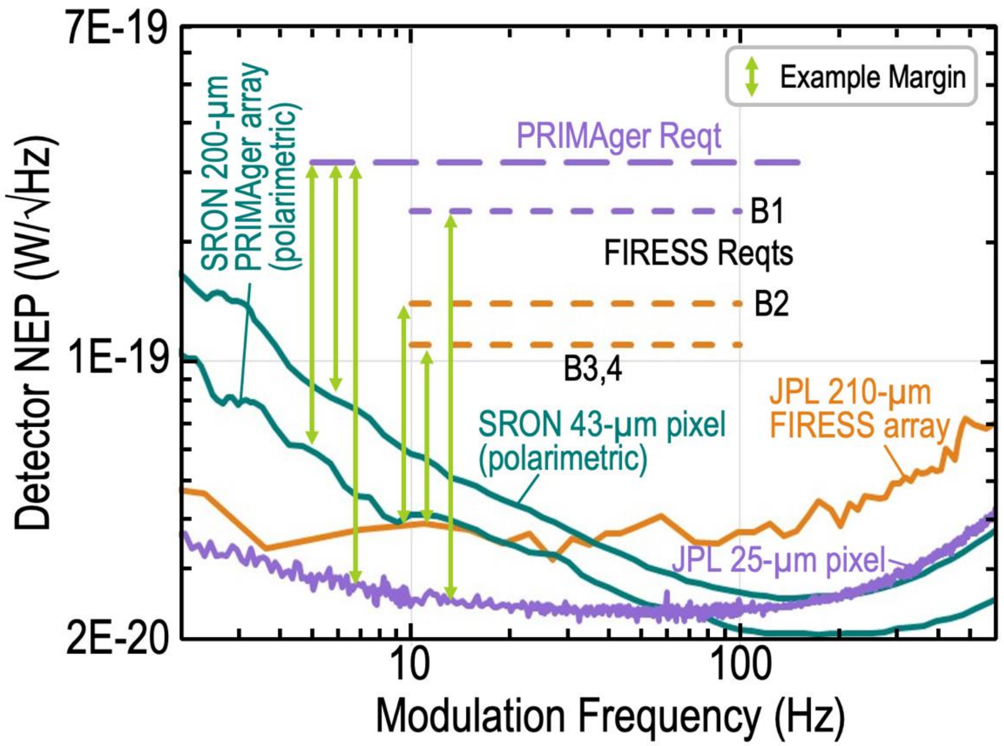


KIDs: Culmination of 2 Decades of Technology Investment



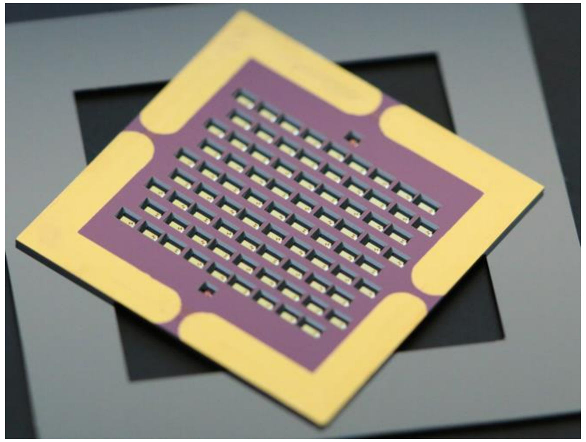
JPL FIRESS prototype KID arrays with GSFC microlenses

Prototype KIDs meet PRIMA requirements



25 μm result: Day+ 2024, Phys Rev X

SRON polarimetric KIDs (derived from SPACEKIDs effort for SPICA)



Getting Involved

- See website for news, events, papers, etc.
- Join the mailing list
- Submit an application to join a working group
- Next scientific conference in Marseille March 31 – April 2 *Dusting Off the Secrets of the Cosmos with PRIMA*

https://primaconf.sciencesconf.org/

Website

GO book v1

Screenshot from a breakout session of the March 2022 GO science white paper early career scientist mentoring workshop.