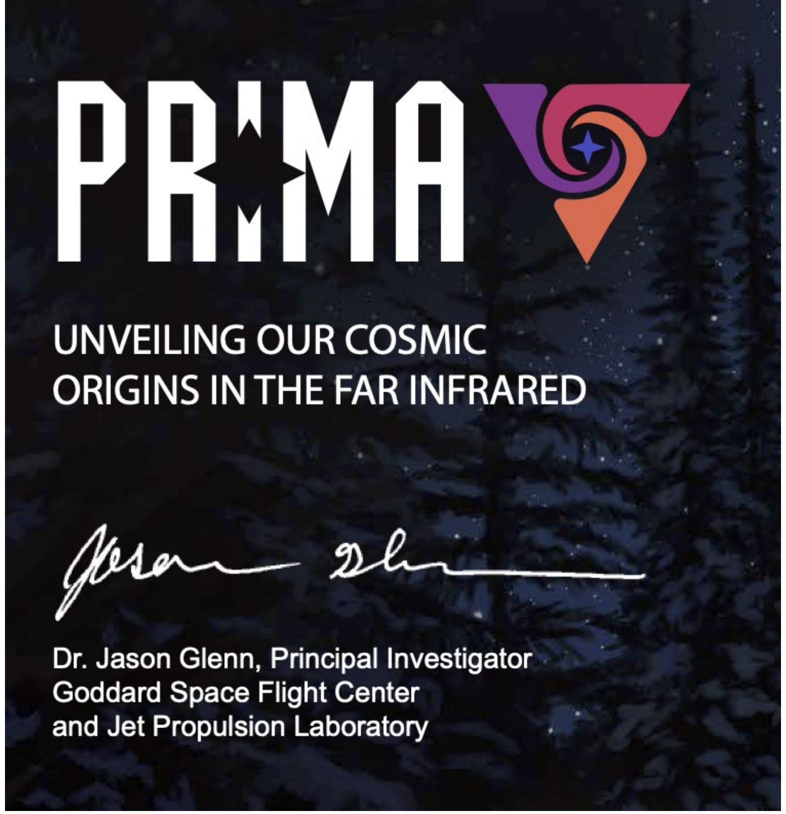


Jan 9, 2024

Matt Bradford

(Jet Propulsion Laboratory, California Institute of Technology)

on behalf of Jason and the PRIMA team.

PI science overview
Instrumentation
Detectors
GO science

Pre-decisional information – for planning and discussion purposes only.

PI: Jason Glenn
DPI: Margaret Meixner

PS: Matt Bradford
DPS: Klaus Pontoppidan

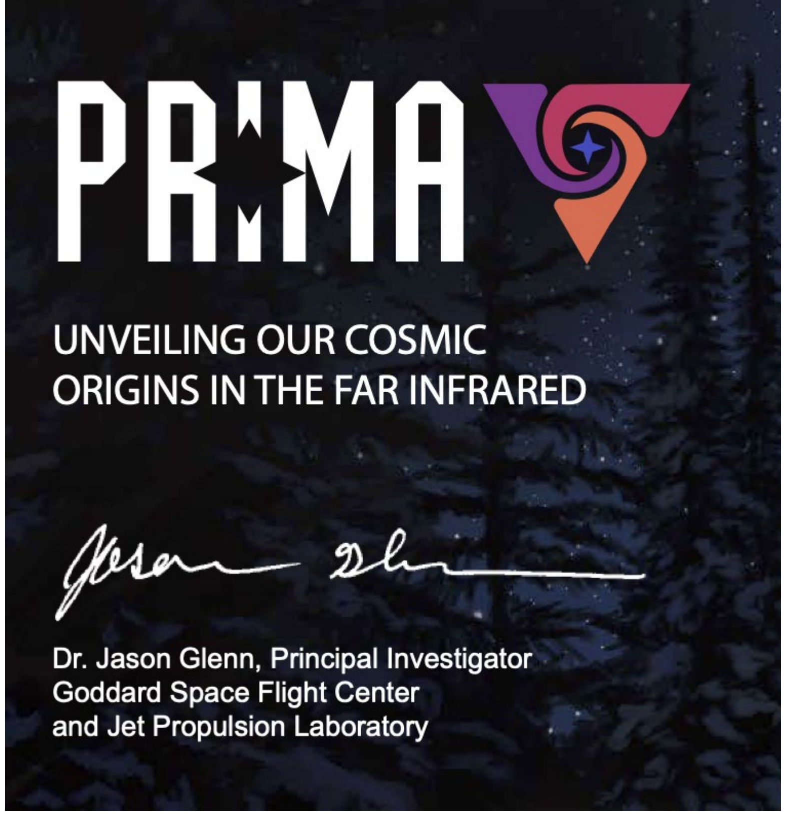
Science Lead: Alexandra Pope
Dep. Sci. lead: Tiffany Kataria

IDEA Lead:
Cara Battersby

Many astronomers providing use cases – kudos !

Excellent engineering / technology teams at JPL, GSFC

Strong JPL formulation team: Jenn Rocca, Liz Luthman, Steve Unwin, w/ D. Richardson @ GSFC



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At AAS

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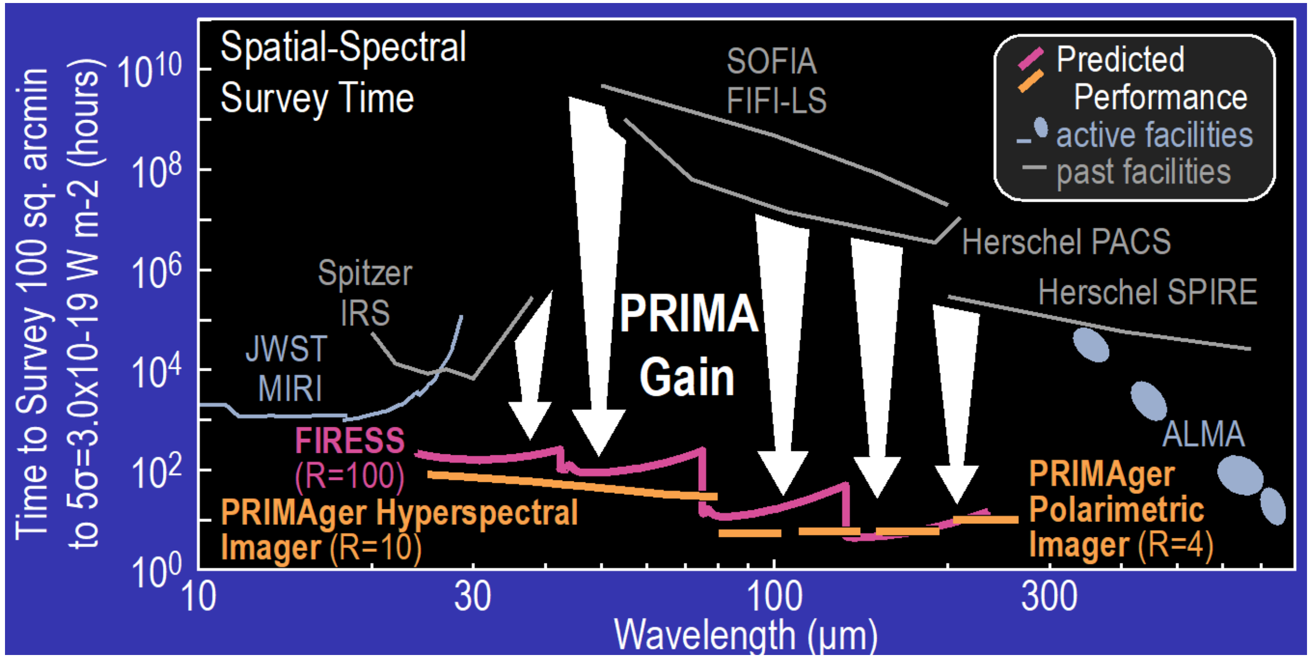
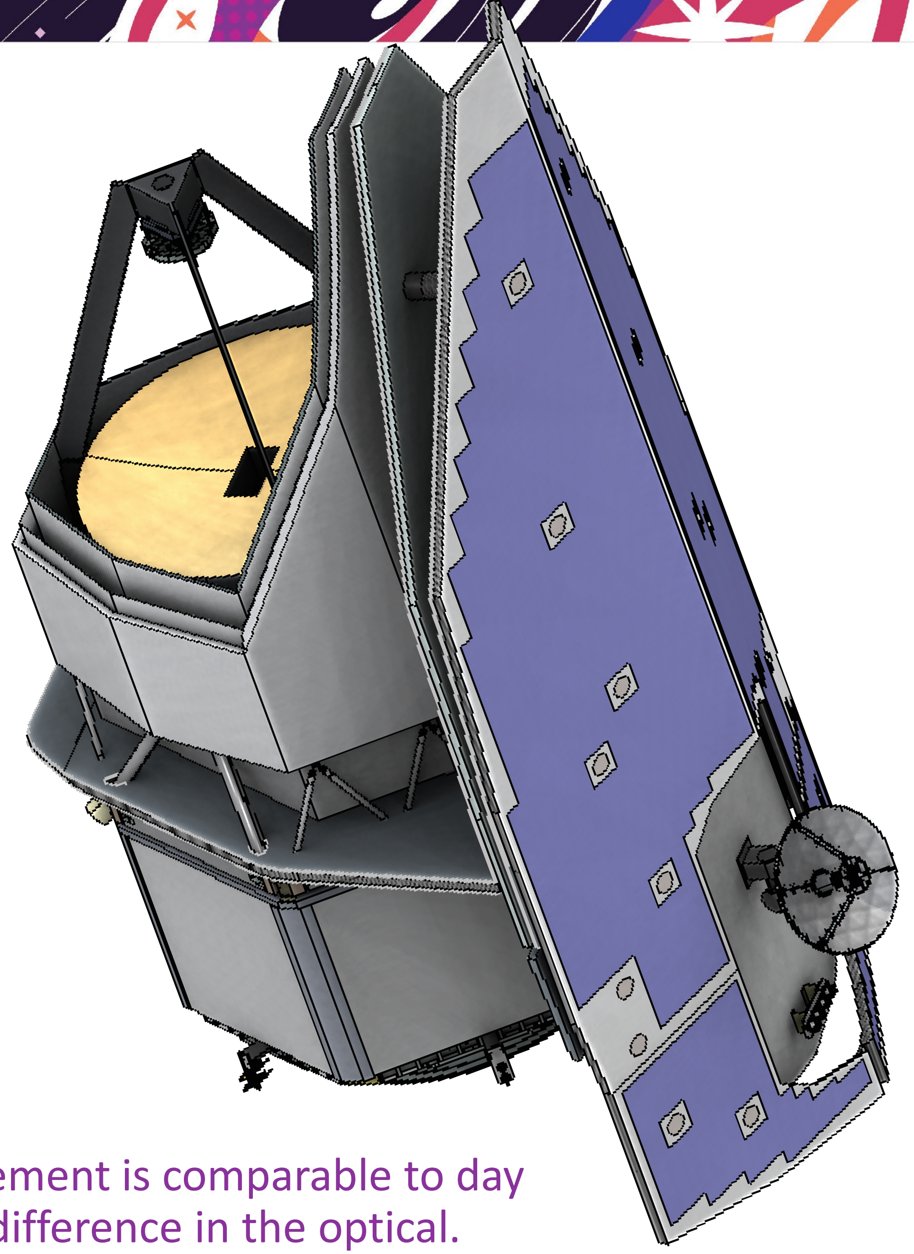
PRIMA at a Glance

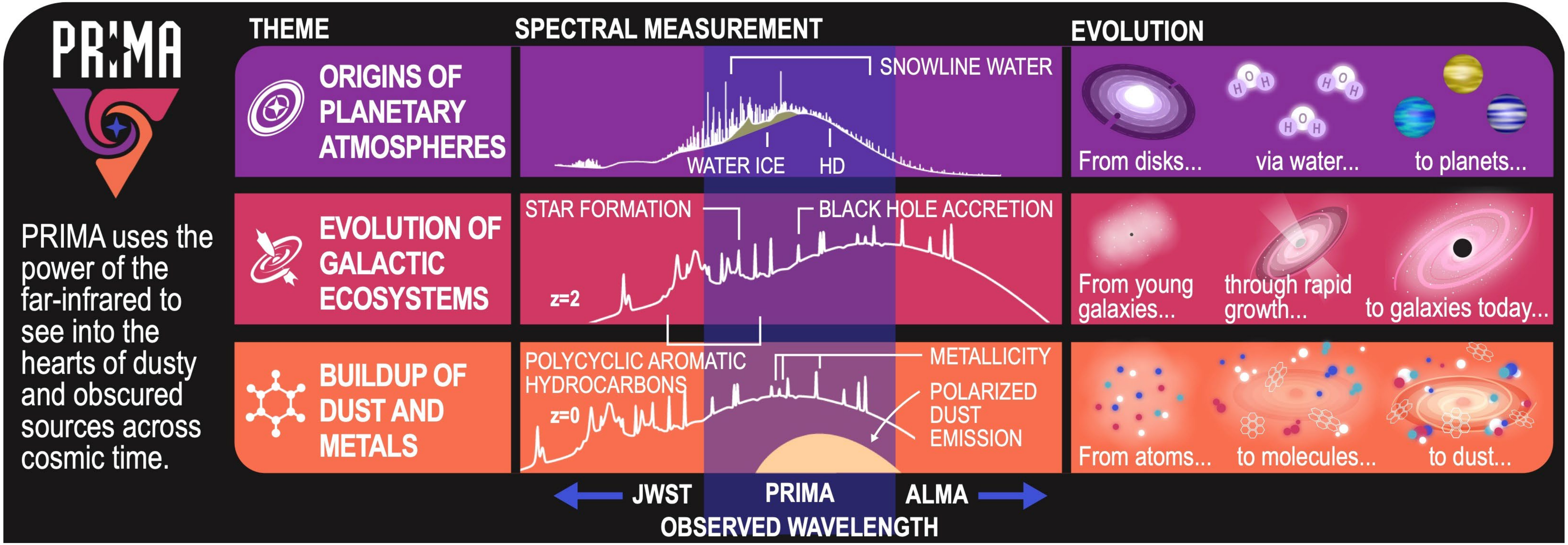
- 1.8-m, all-aluminum telescope cooled to 4.5 K.
- PRIMAger imager and polarimeter (France / Holland): 25-80 microns R=10 hyperspectral imaging, 91-232 μm imaging polarimetry.
- FIRESS Spectrometer (JPL w/ GSFC) : 24-235 μm in 4 grating modules with R>85. High-res mode gives R of thousands across full band.
- 100 mK focal planes with kinetic inductance detectors, provided by joint JPL/ GSFC and SRON team.
- JPL lead with GSFC, Ball spacecraft, IPAC data handling, many others.





Improvement is comparable to day / night difference in the optical. Requires a cold (~5K) telescope and sensitive far-IR detectors.

PRIMA PI Science Programs: Exercises the observatory, and provides legacy datasets



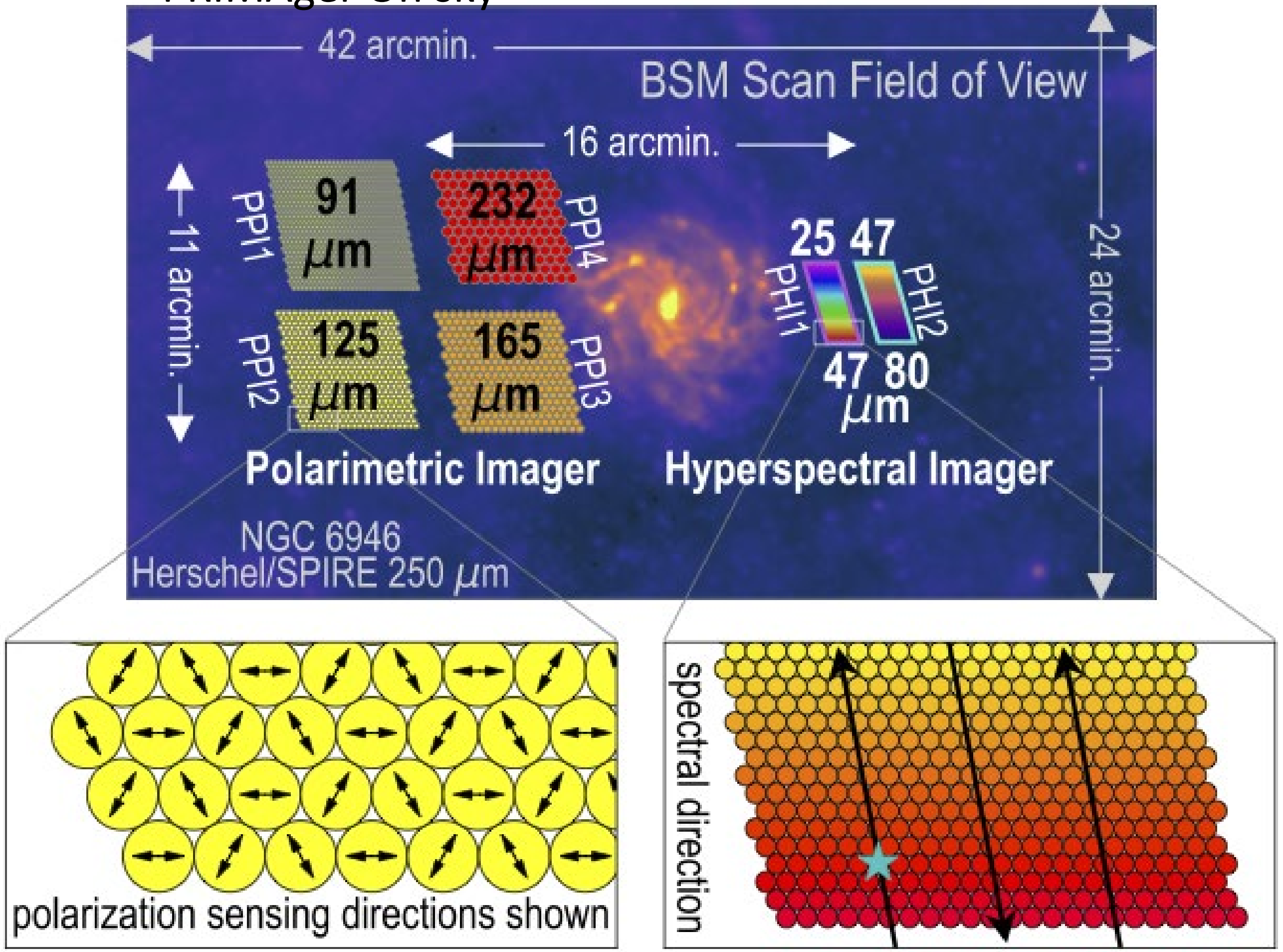
Planetary Atmospheres → High-res spectroscopy across the full 24-235 μm band. R = 4,400 at 112 μm

Galactic Ecosystems → Hyperspectral blind imaging surveys, follow-up full band spectroscopy for fine-structure lines, PAHs at z=1 to 2.3 → Full-band medium res spectroscopy for outflows

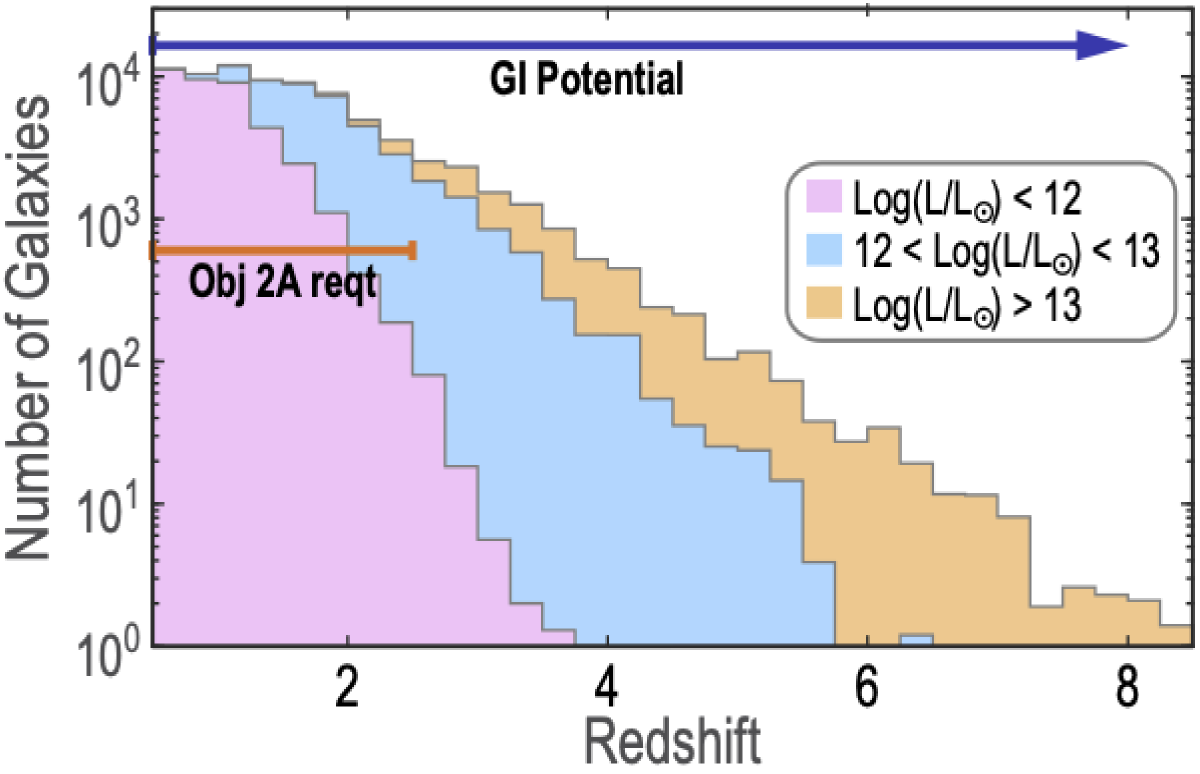
Dust and Metals → Hyperspectral blind imaging surveys, follow-up full band spectroscopy for fine-structure lines, PAHs at z=1 to 2.3 → Polarimetry at 90-235 μm

PRIMAger Instrument (Leads Denis Burgarella, Laure Ciesla, Marc Sauvage)

PRIMAger On sky



Hyperspectral Survey Yields

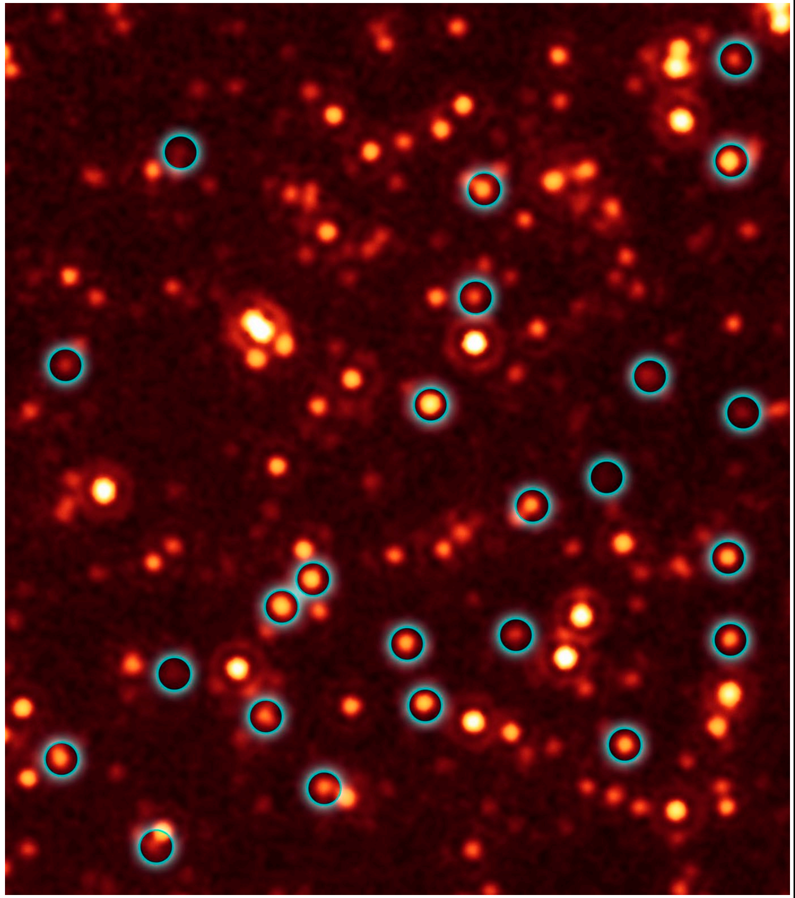


- 2 hyperspectral focal planes using linear variable filters with continuous R=10 coverage.
- 4 single-band polarimetric focal planes
- Whole instrument read out simultaneously.

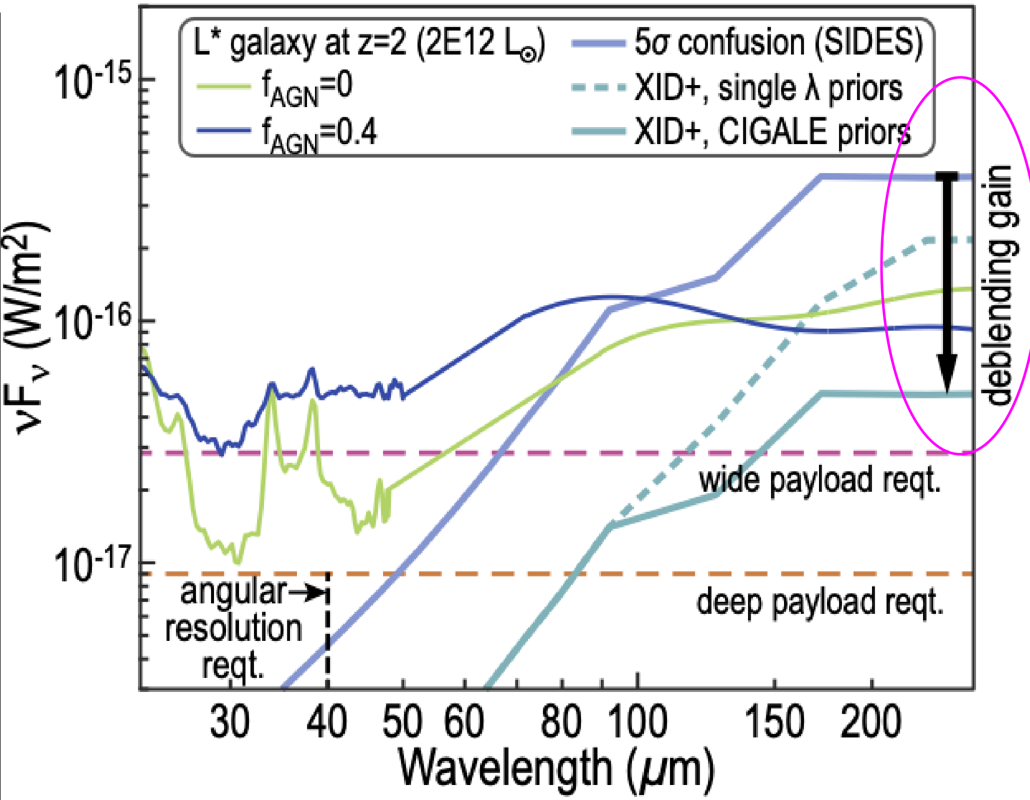
- 2 tiered survey with 1 square degree and 10 square degree tiers. GO could do additional tiers.
- Expect ~ 10,000 galaxies per delta z = 0.25 bin. A rich archival dataset.

Source Confusion with PRIMA

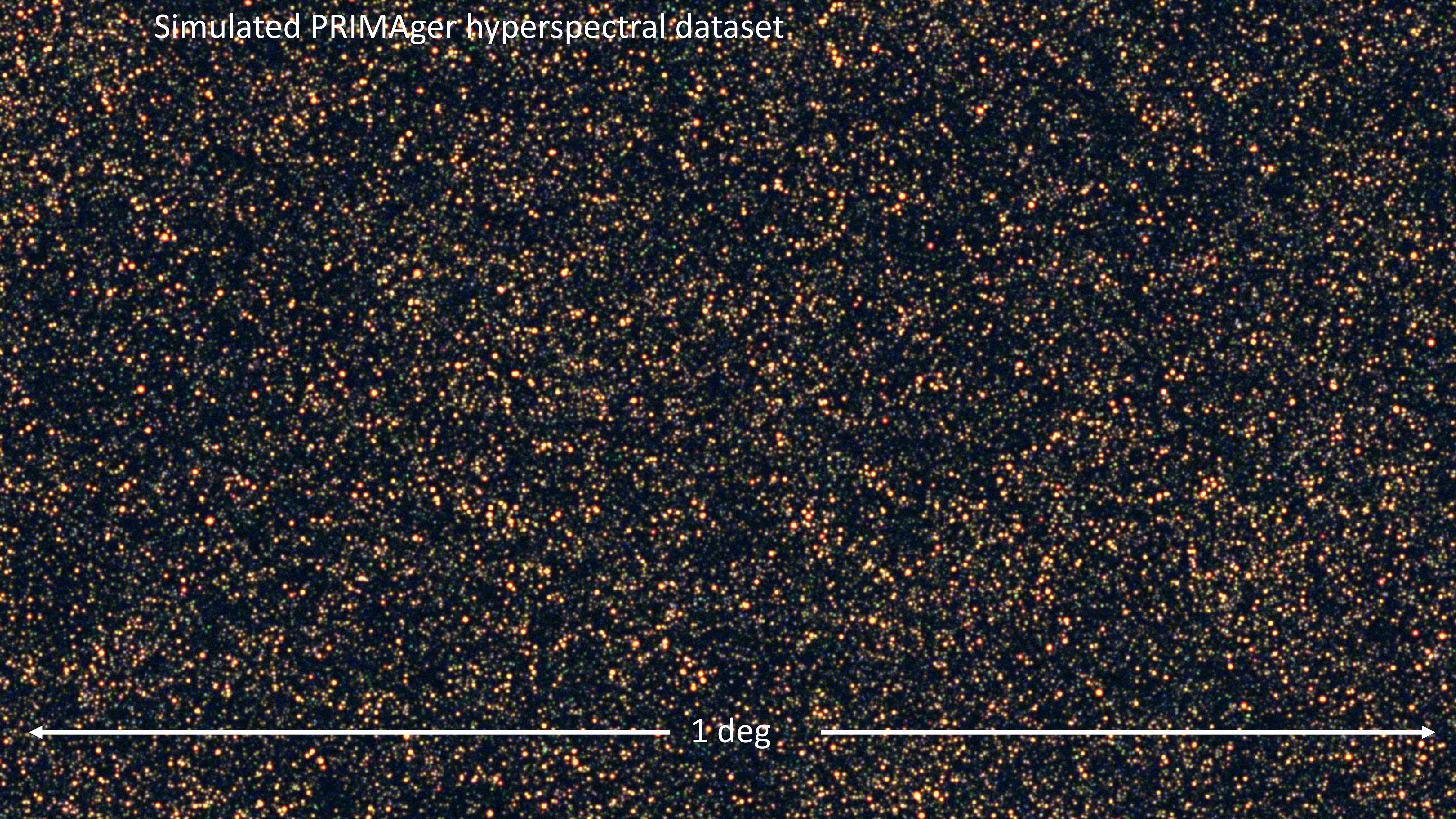
Spitzer MIPS 24 micron



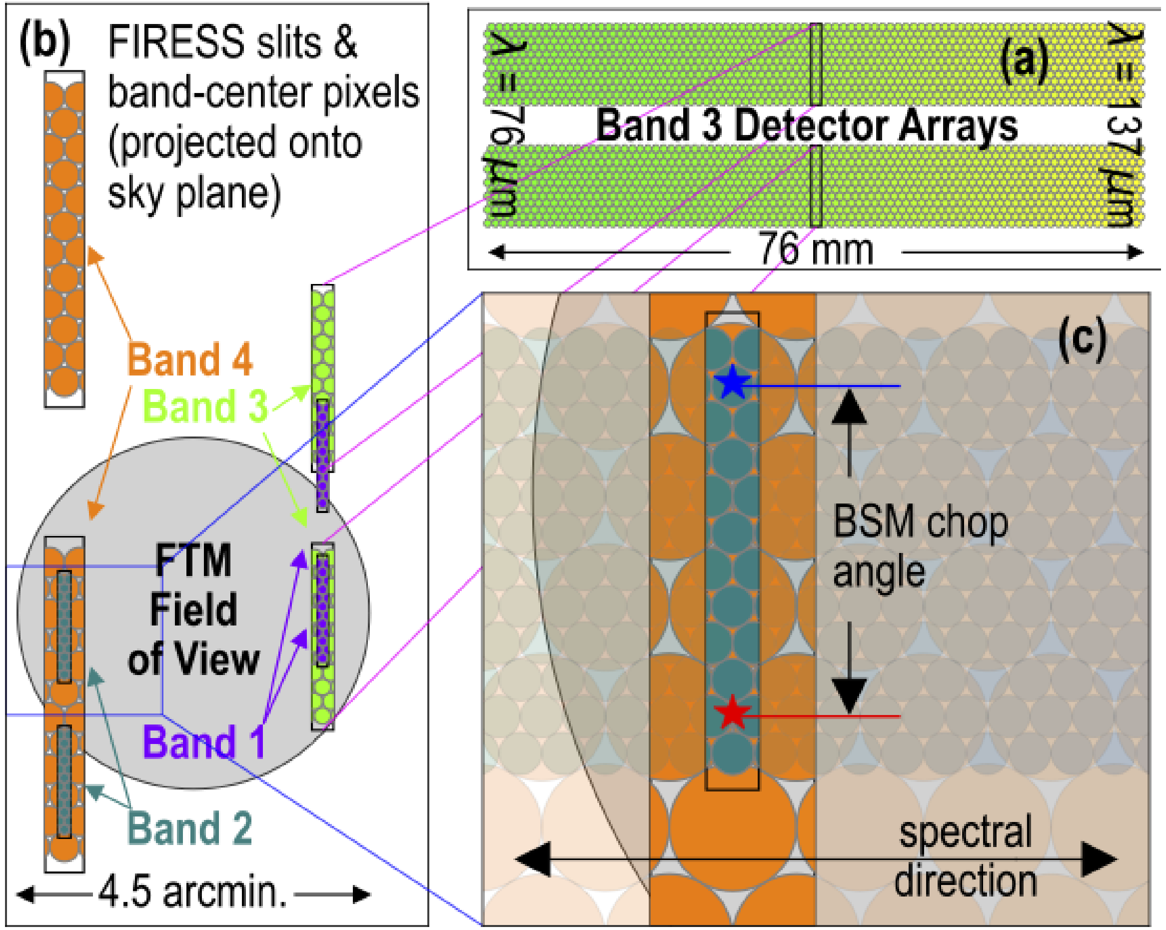
- Nearly all PRIMA sources will have position and redshift priors with Euclid / Roman surveys.
- Beamsize with PRIMA at 55-60 µm will be comparable to Spitzer 24 µm, which was unconfused and resolved most of the light. Expect the same for PRIMA but reaching further into the far-IR. Use short-wavelengths positions as priors to long-wave extraction (see right).
- Black hole growth / star formation ratio is measured with fluxes shortward of 90 microns.
- Confusion mitigated with spectroscopy – unconfused in line counts.

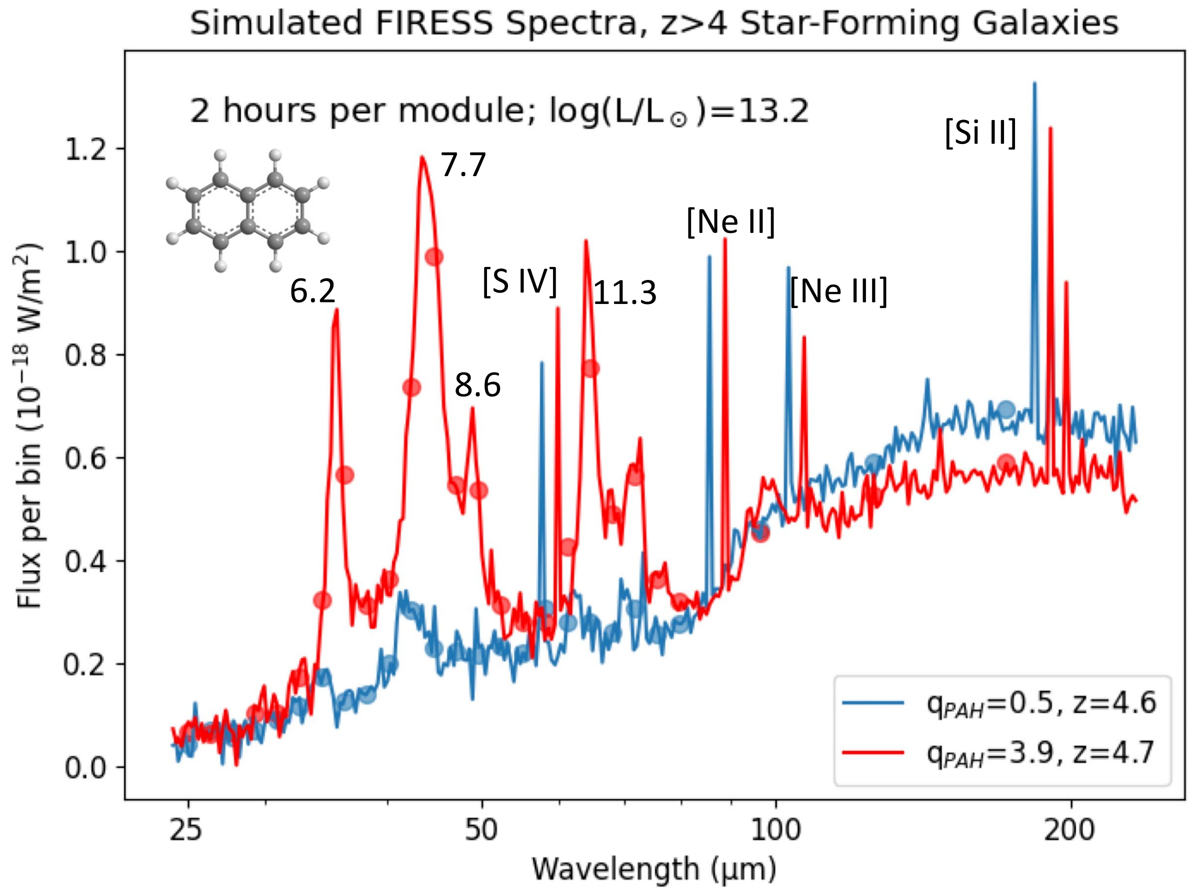


- XID+ deblending demonstrated with Herschel PACs and SPIRE datasets.
- Uses prior information on both position and flux.
  - Starts with shortest-wavelength map, uses previous flux as prior.
  - CIGALE-based approach uses prior based on all shorter-wavelength data. -> 8x improvement in depth


Simulated PRIMAger hyperspectral dataset
1 deg

FIRESS Instrument

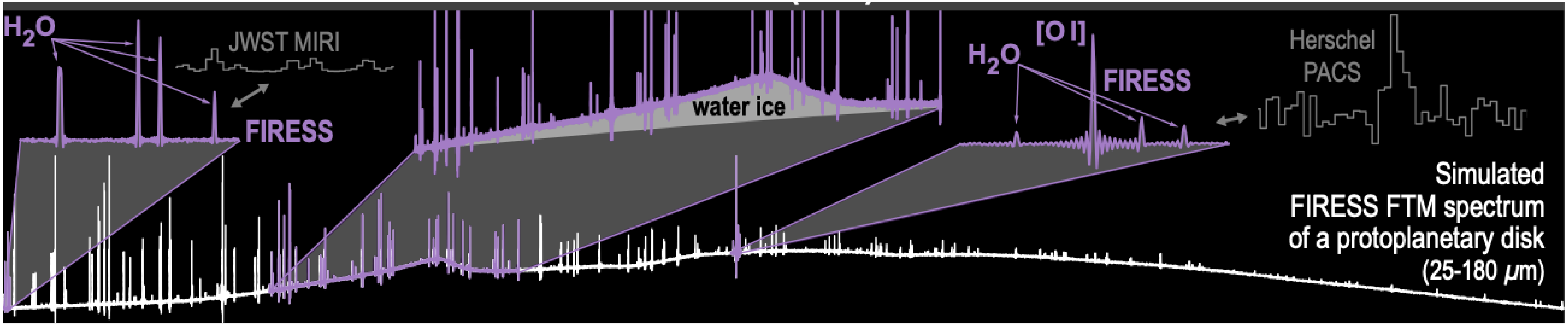




- 4 slit-fed grating modules, each 24 x 84 pixels w/ gap.
- Bands 1 and 3 overlap, Bands 2 and 4 overlap.
- 2 pointings for full spectrum, though all 4 bands read out.
- High-res mode couples all bands when engaged

Simulated PRIMA/FIRESS spectra of two luminous galaxies at z > 4.5, with realistic noise model reflecting current best estimate FIRESS sensitivity. Dots are example PRIMAger binned fluxes. *From Donnely et al contribution to PRIMA GO book.*

FIRESS high-res FTM module



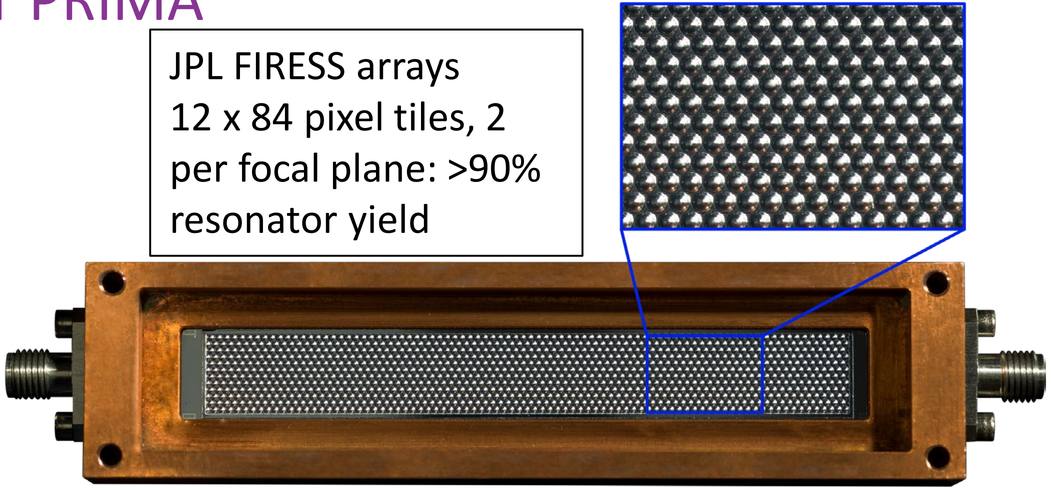
- When engaged, picks off light from telescope in collimated space
- Serves the full band simultaneously (2 pointings required for a source)
- Path length can be tuned, provides up to R=4,400 at 112 microns
- R scales as 1/lambda. So can resolve water lines in Band 1.

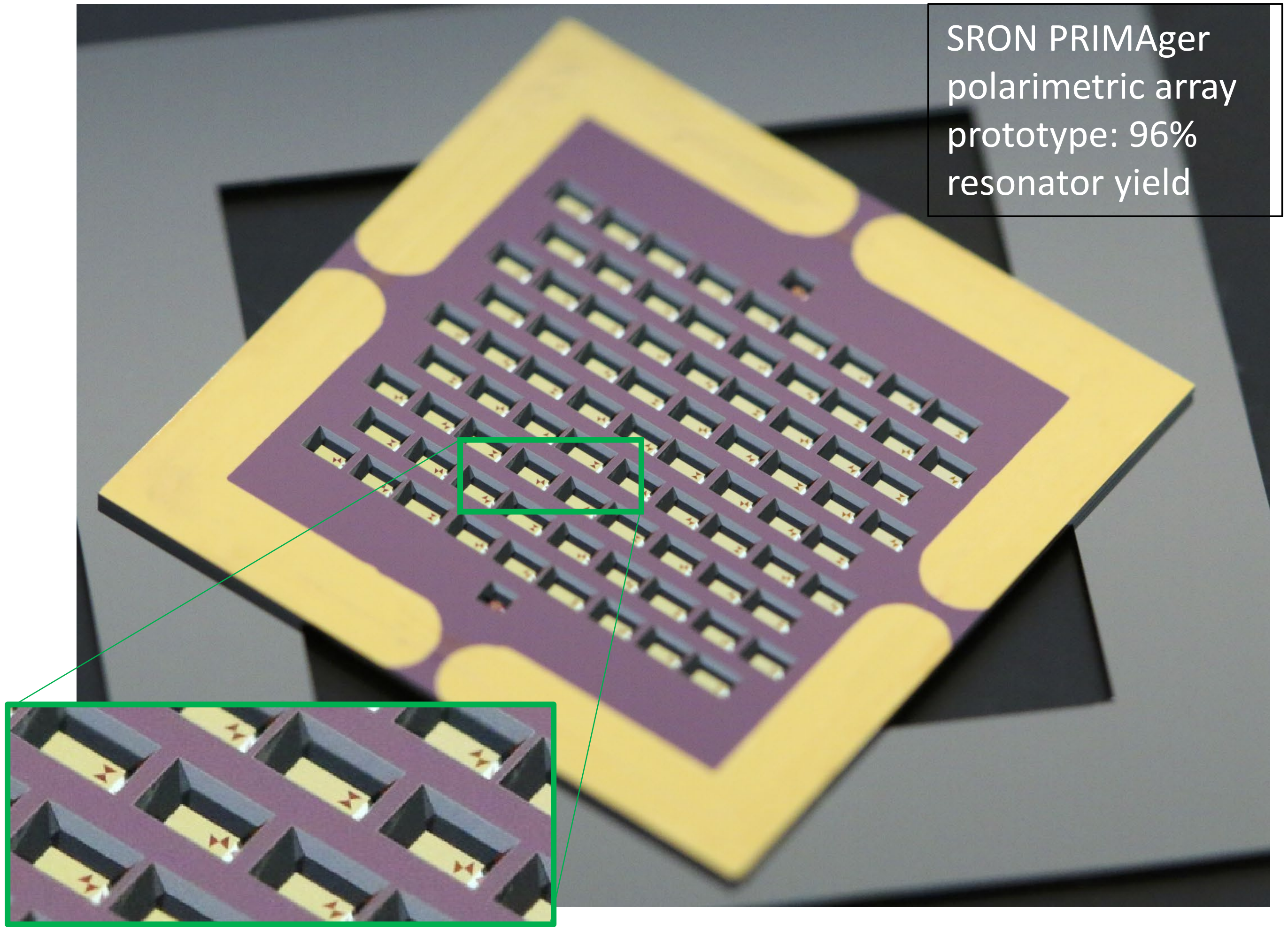
Heritage: Herschel SPIRE FTS also 4.5 K imaging FTS. (Griffin et al.)
Same Canadian team developing the low-power-dissipation scan mechanism.

KID Detectors: a JPL / GSFC / SRON Collaboration for PRIMA

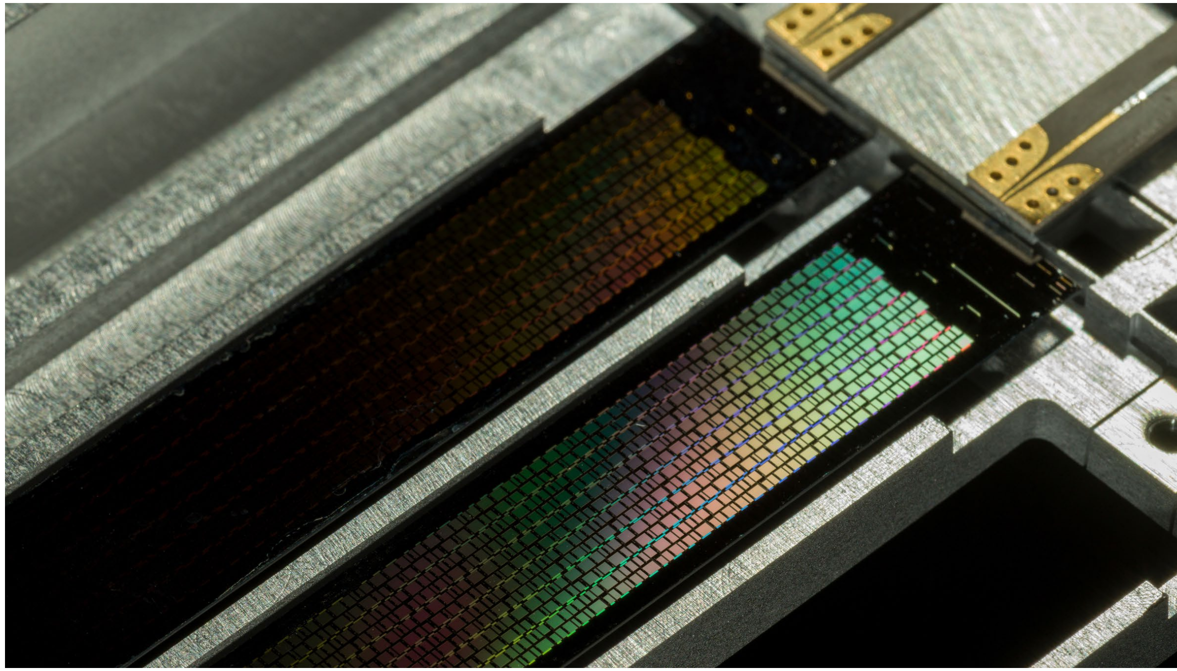
- ***Sensitivity exceeds performance requirements over full wavelength range.***
- Demonstrated detector/lenslet hybridized arrays with full FIRESS format (84x12, 900-µm pixel pitch). PRIMAger prototypes in place from SRON.
- Key remaining challenge is yield with lenses bonded and full-band readout.

JPL FIRESS arrays
12 x 84 pixel tiles, 2 per focal plane: >90% resonator yield

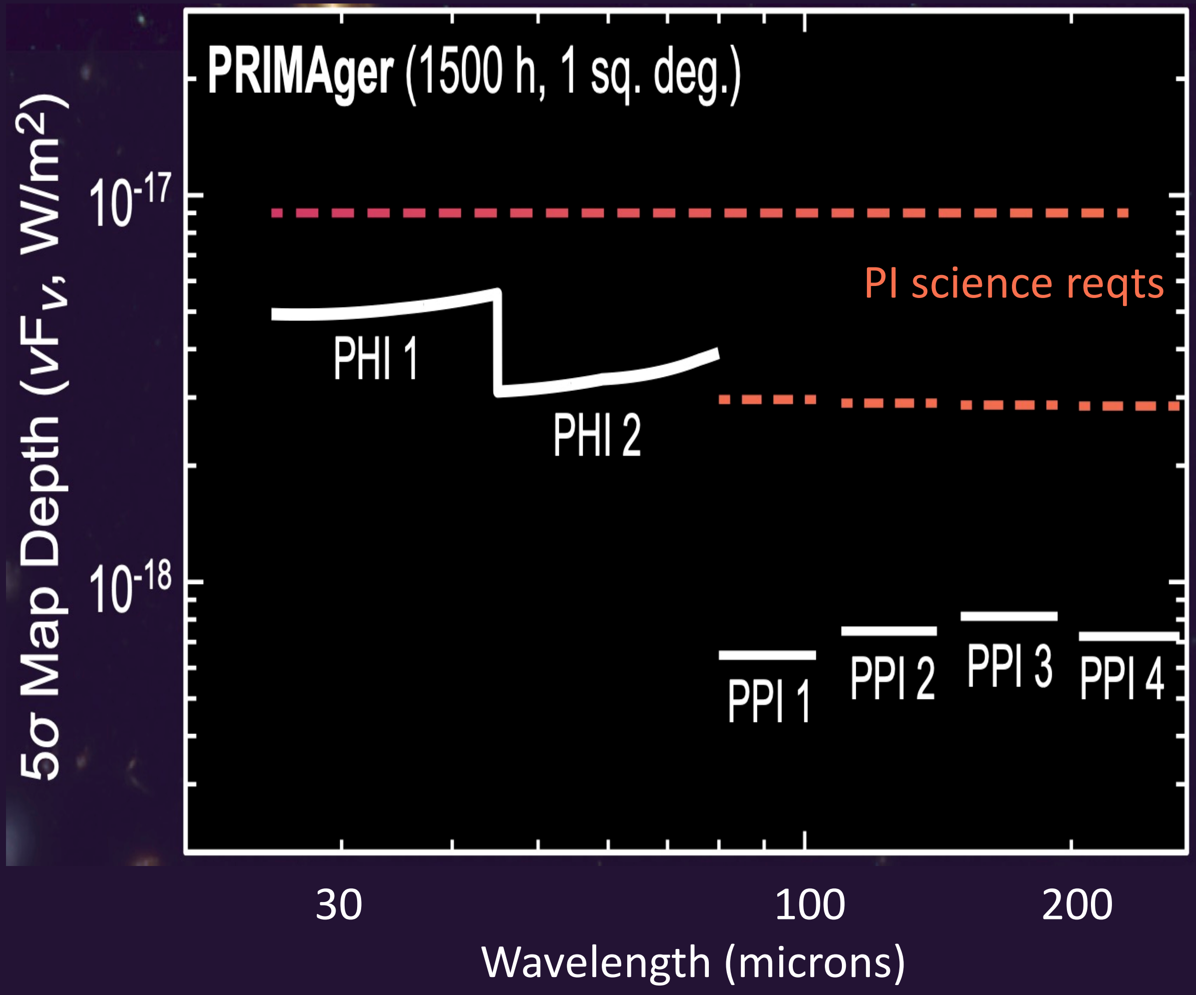


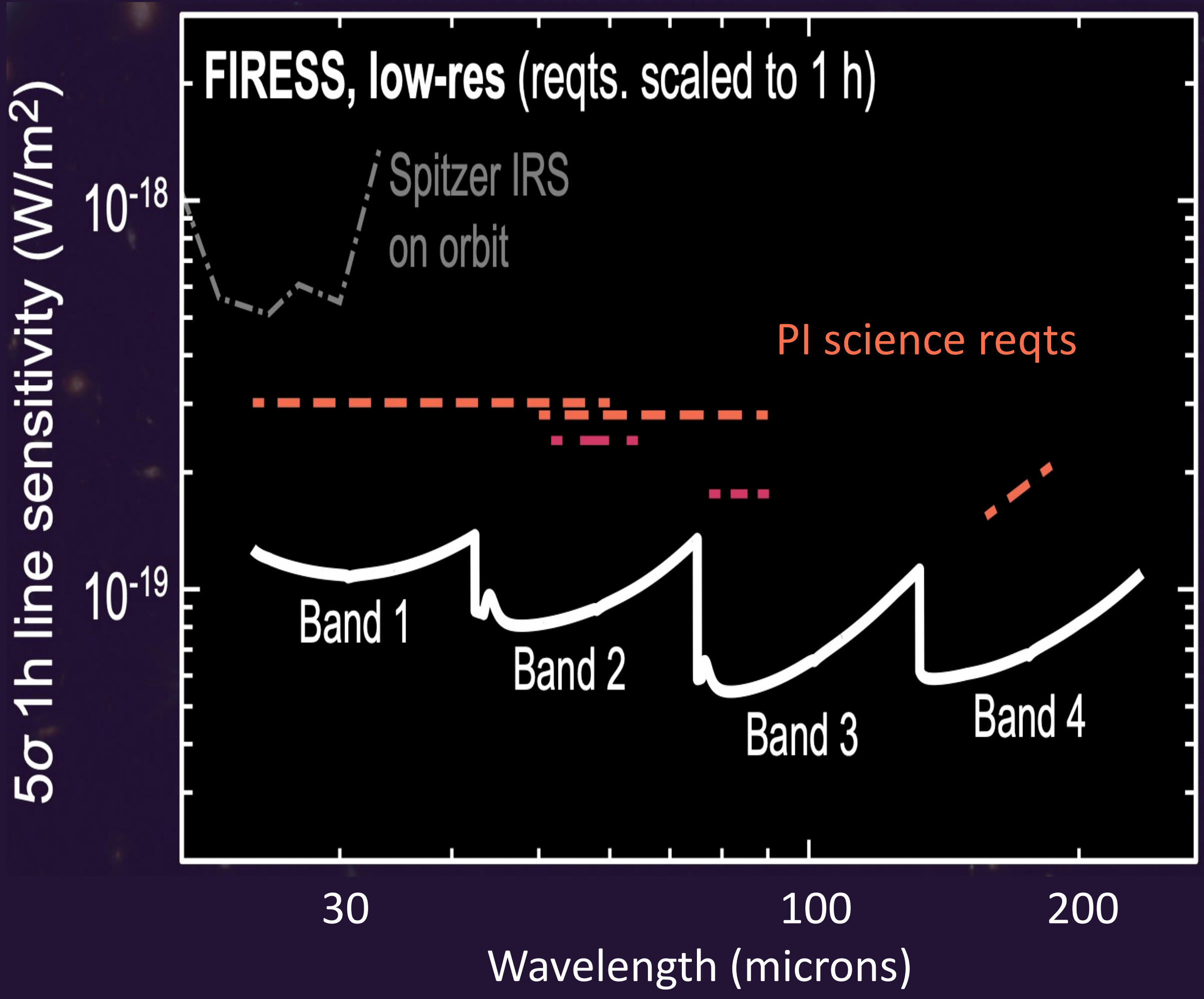


SRON PRIMAger polarimetric array prototype: 96% resonator yield



PRIMA Sensitivities

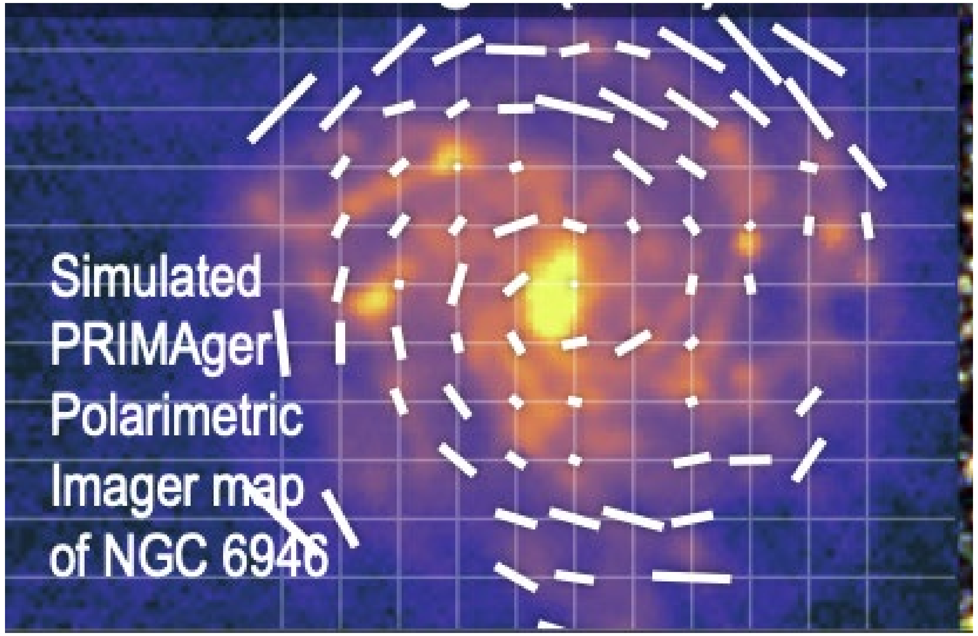


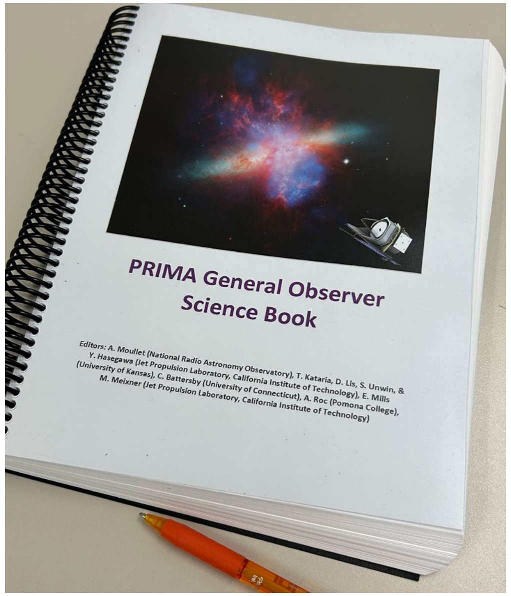


Includes: all key optical efficiencies, microlens & pixel coupling to sources, grating blaze
detector sensitivity, background photons
temporal efficiencies due to chopping, cosmic ray removal.

PRIMA GO Opportunities

- Sensitivities available on fact sheet and web page.
  - PRIMAger (mapping speed)
  - FIRESS (pointed – mapping #s on web page)
  - FIRESS high res (pointed)
- Instantaneous field of regard of 26% of the sky.
  - Investigating larger FoR – current limits very conservative. Have margins in thermal lift and mass so could increase sunshade area.
- Agile. Can slew and anywhere in field of regard in 12 minutes
- No meaningful constraints on changing instruments or modes.
- GO book a set of example fiducial cases. Thanks very much to those of you that contributed. More to come.
- Remember, NASA will control the GO program.
- Reach out with questions.





prima.ipac.caltech.edu

Thank you

PRIMA activities at AAS (other than this session)

Monday 9-10: Poster Session 106:
Steve Unwin et al., PRIMA Planetary System Formation

Wednesday 9-10, Poster Session 306
Betsy Mills et al., PRIMA Galactic Ecosystems

Wednesday 5:30-6:30: Poster Session 306
Arielle Moullet et al.: PRIMA GO Book

Thursday 1-2, Poster Session 457
Matt Bradford et al. – FIRESS
Margaret Meixner et al. – PRIMAger
Johannes Staguhn et al. – Rise of Dust and Metals

Thursday 2-3:30: Oral 450:
Margaret Meixner et al., PRIMA overview

Tuesday evening: Informal Social Event
8:30pm at the New Orleans Social House

PRIMA folks at AAS 243


Lee Armus


Matt Bradford


Denis Burgarella


Tiffany Kataria


Margaret Meixner


Arielle Moullet


Steve Unwin

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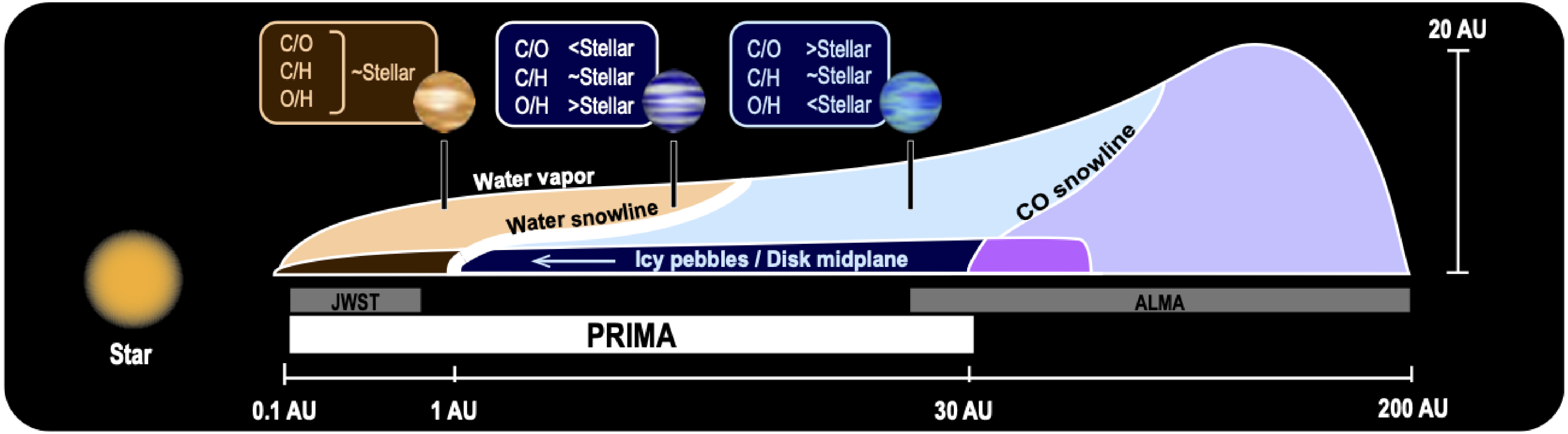
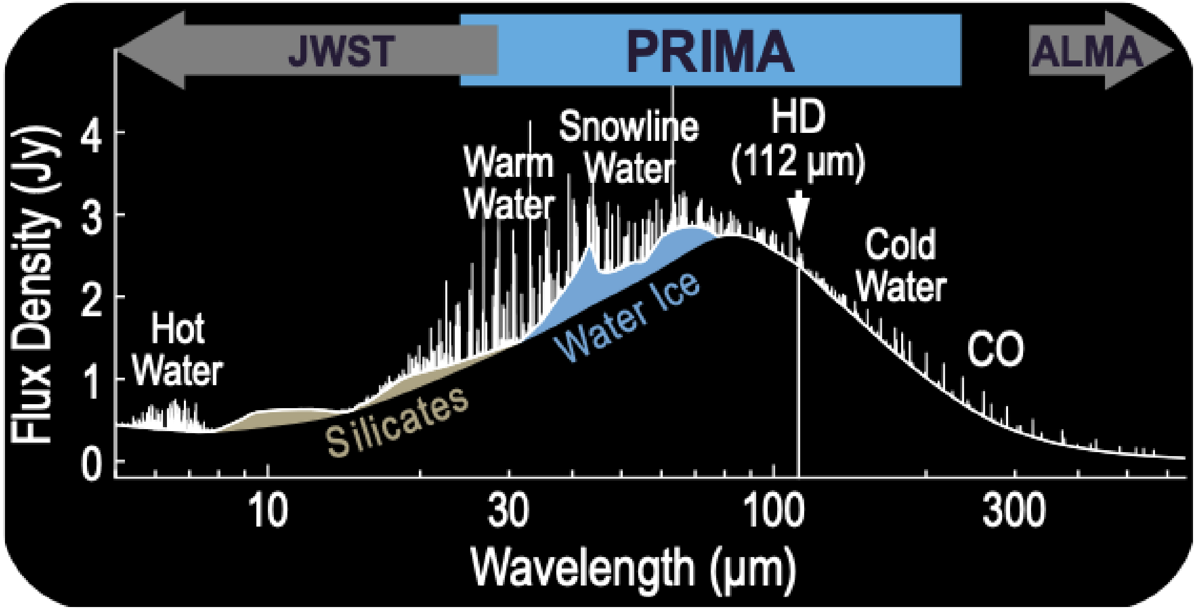
PRIMA PI Theme 1: How do Exoplanets and their Atmospheres Form?



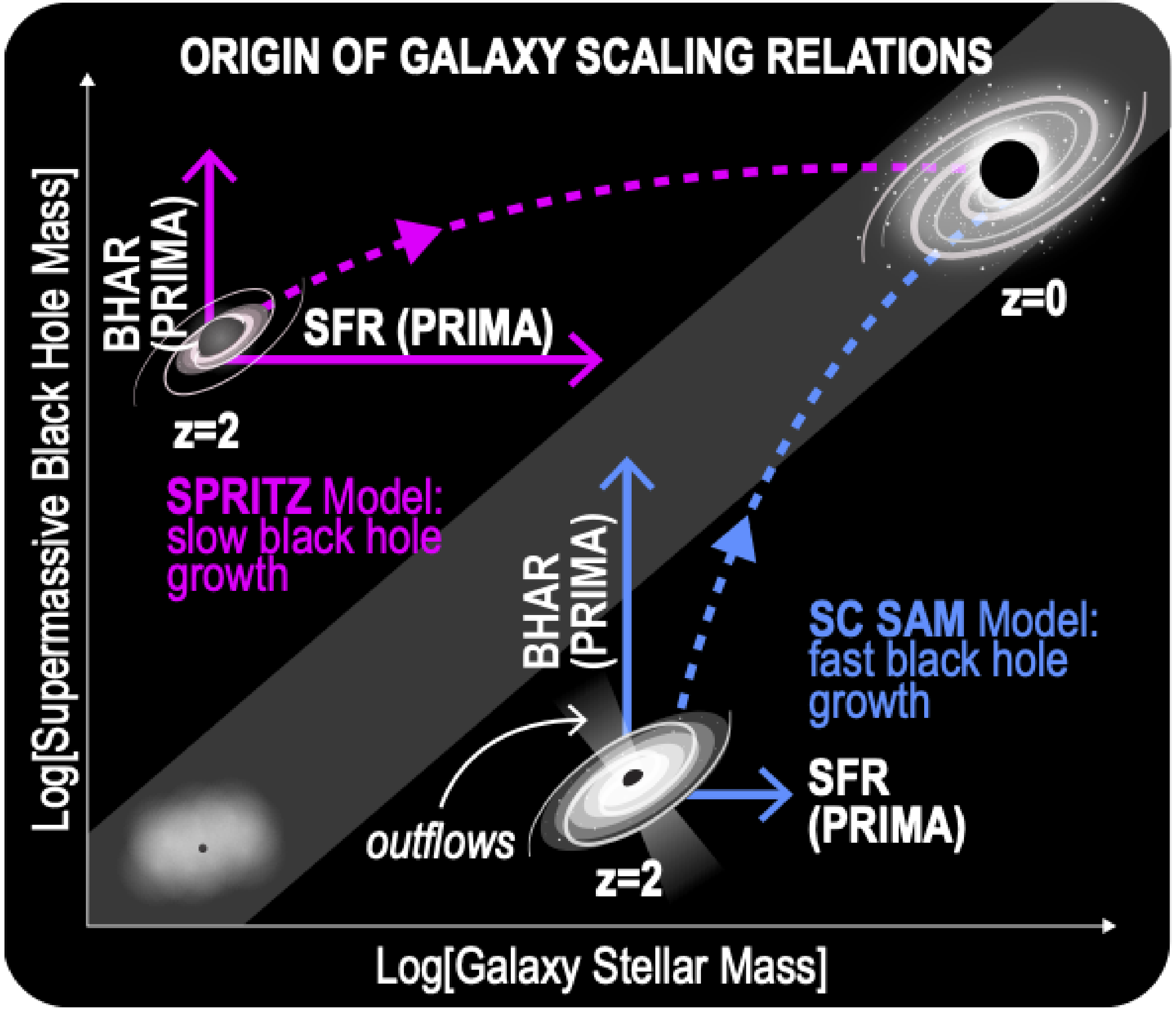


PRIMA connects water, oxygen, and carbon in protoplanetary disks to compositions of exoplanet atmospheres to constrain models of planet formation. The approach is full-band high-resolution far-IR spectra of 200 disks spanning ages and stellar types. Each disk spectrum provides:

- Key water lines only accessible in the far-IR which test theories of water's role in driving planet formation.
- The HD 112 micron line which provides total gas masses and thus carbon (C) and oxygen (O) abundances in disks to reveal where exoplanets form.

No such complete far-IR disk spectra exist at present.

PRIMA PI Theme 2: How do supermassive black holes and galaxies co-evolve?



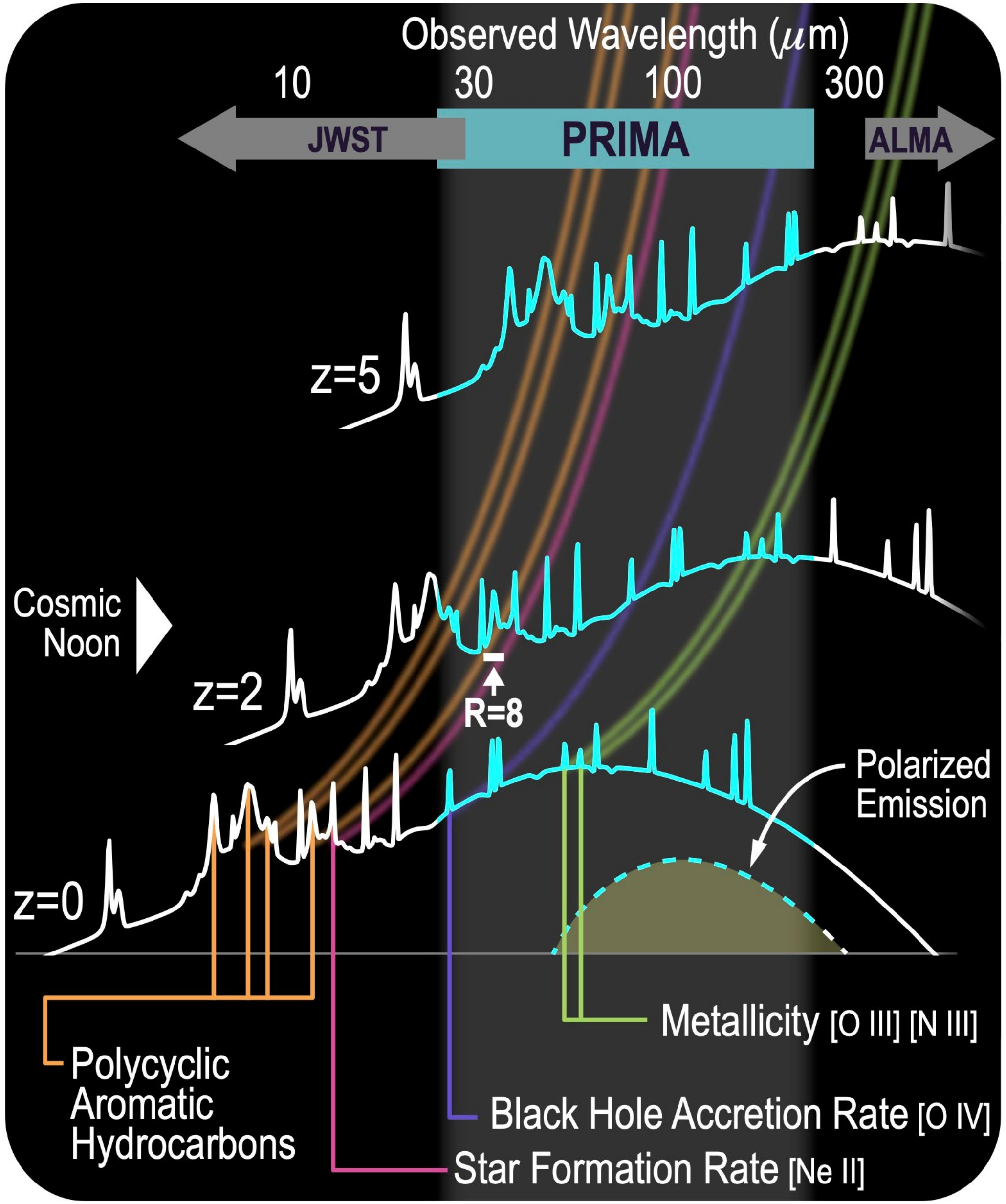
The modern universe shows an uncanny connection between galaxies' stellar masses and their supermassive black hole masses, even though they differ in scale by a factor of ~400.
How did this happen?

With far-IR tracers, PRIMA simultaneously measures black hole accretion rate (BHAR) and star formation rate (SFR) in massive galaxies from cosmic noon to the present day to establish how they are linked.

- First is an unbiased field-filling survey with the PRIMAger hyperspectral bands, giving R=10 spectrophotometry in the rest-frame mid-IR for thousands of galaxies. Each galaxy spectral energy distribution (SED) reveals the ratio of black hole growth to stellar growth.

- Then, individual galaxies are then targeted for detailed FIRESS spectroscopic follow-up, providing robust nebular gas-phase measures of black hole accretion, star formation, and molecular outflow rates.

PRIMA PI Theme 3: How do interstellar dust and metals form and build up in galaxies?

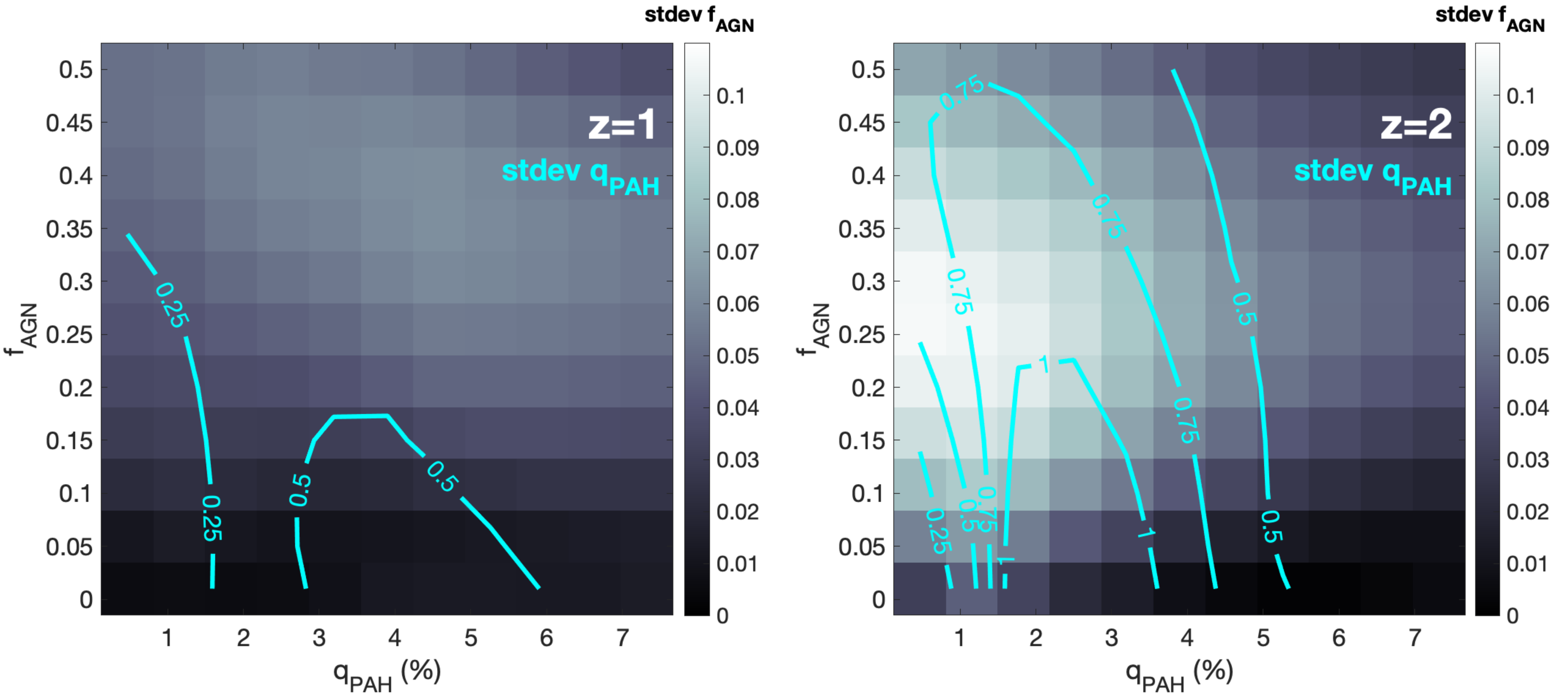


Heavy elements (heavier than He) and dust are vital to the energy flow in galaxies and the development chemical complexity as the Universe evolves, but their origin and composition are not well understood.

PRIMA quantifies the dust properties and metal content of dusty galaxies from cosmic noon to diverse environments in galaxies today.

- PRIMA measures both polycyclic aromatic hydrocarbon emission and gas-phase heavy element abundances in galaxies at cosmic noon, linking small grains to metallicity when the Universe was most vigorously creating heavy elements and dust.
- PRIMA determines the fraction of interstellar dust that is freshly ejected by stars (stardust) versus dust grown in the interstellar medium (ISM-mixed dust) by measuring the wavelength dependence of far-IR dust polarization in nearby galaxies.

Extraction tests using CIGALE templates. Uses hyperspectral data only (shortward of 84).



f_{AGN} is reliably extracted as long as q_{PAH} is not too small.