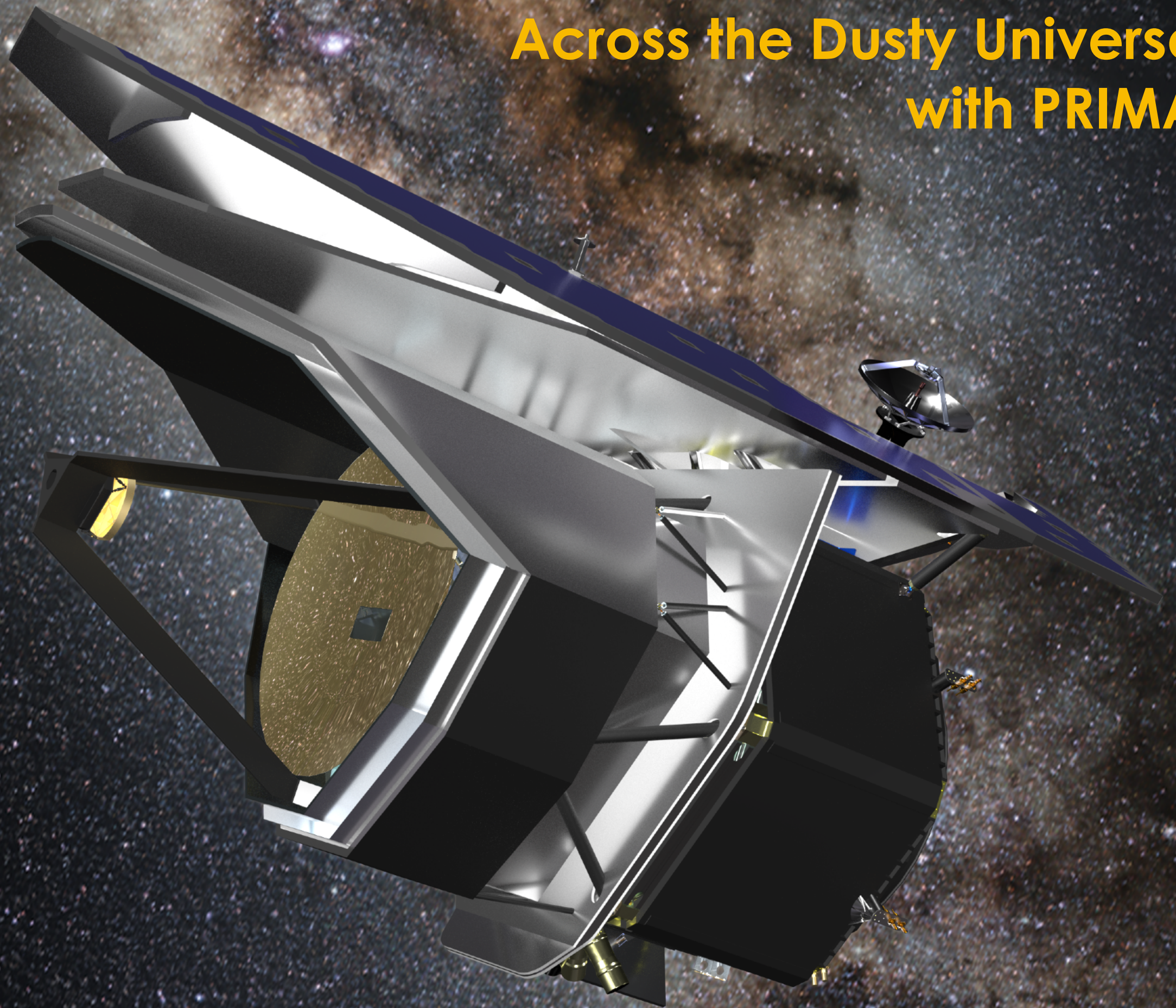


Across the Dusty Universe with PRIMA



JD Smith
University of Toledo

Meet the 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
(prev. Ball) • ASI / INAF •
Cardiff • IPAC • LAM •
MPIA • SRON

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



PI: Jason Glenn

DPI: Margaret Meixner

PS: Matt Bradford

DPS: Klaus Pontoppidan

Science Lead: Alexandra Pope

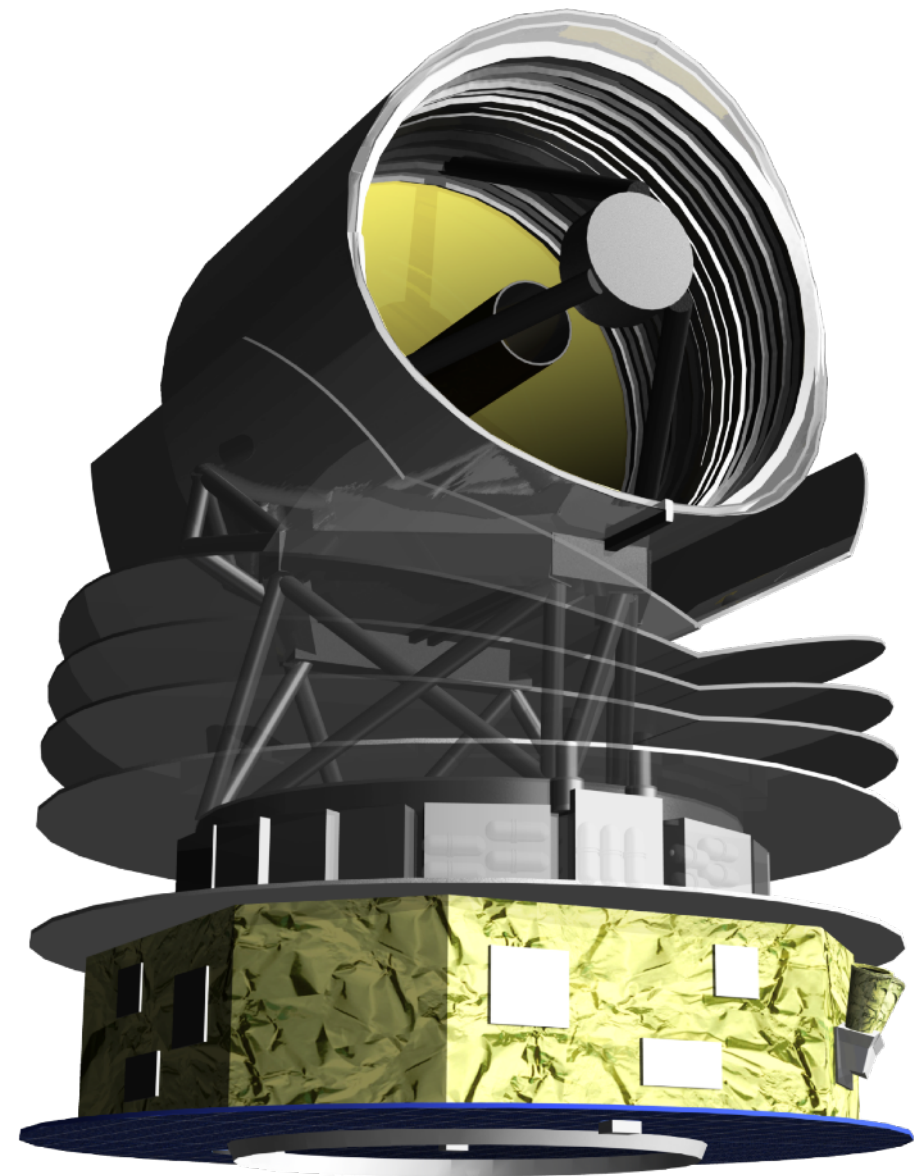
Dep. Sci. lead: Tiffany Kataria

PRIMA in a nutshell

PRIMA has:

LEGACY

Builds on *decades*
of advanced
space-FIR
observatory
concepts



JAXA / SPICA Team

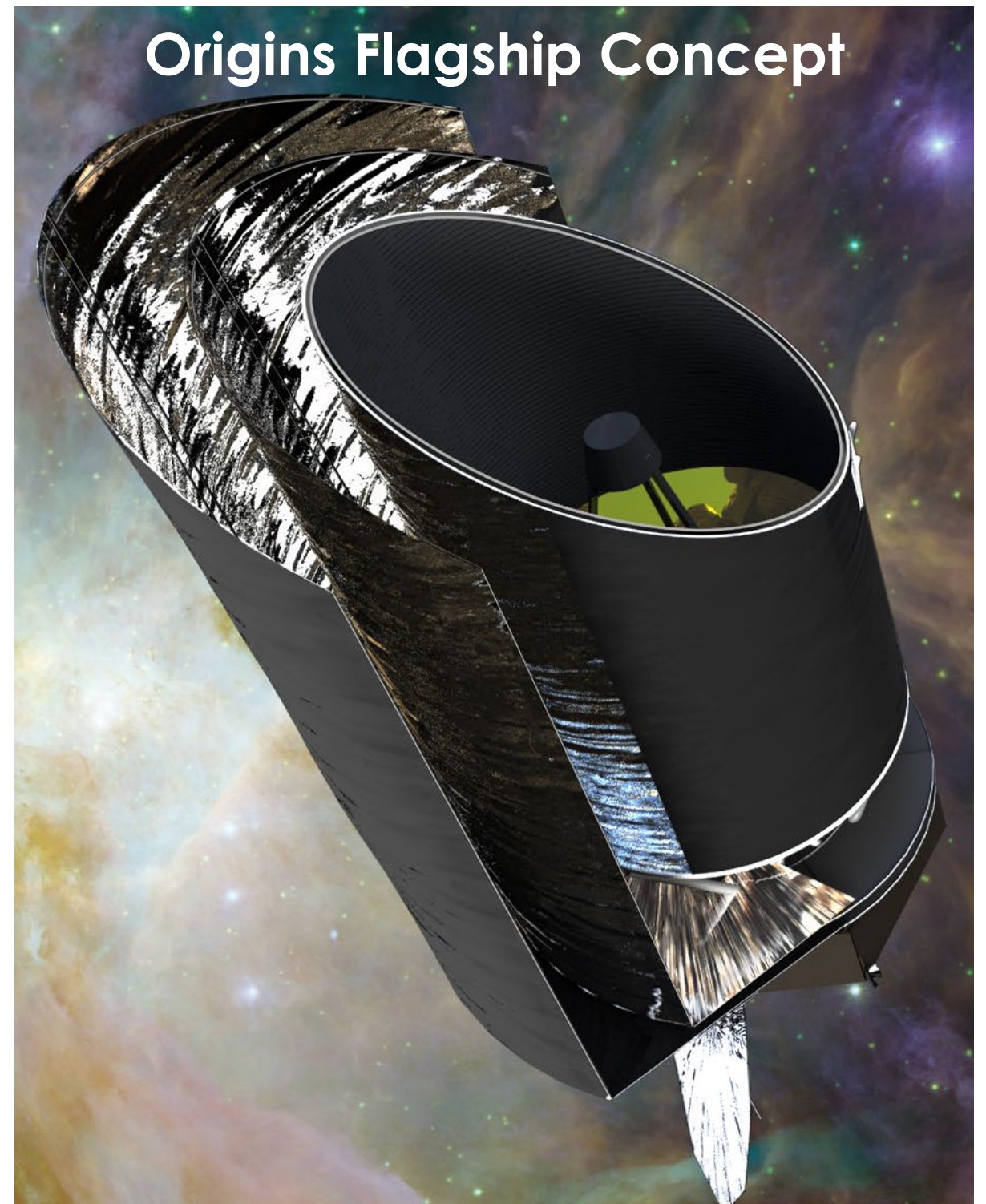
SPICA

PRIMA in a nutshell

PRIMA has:

LEGACY

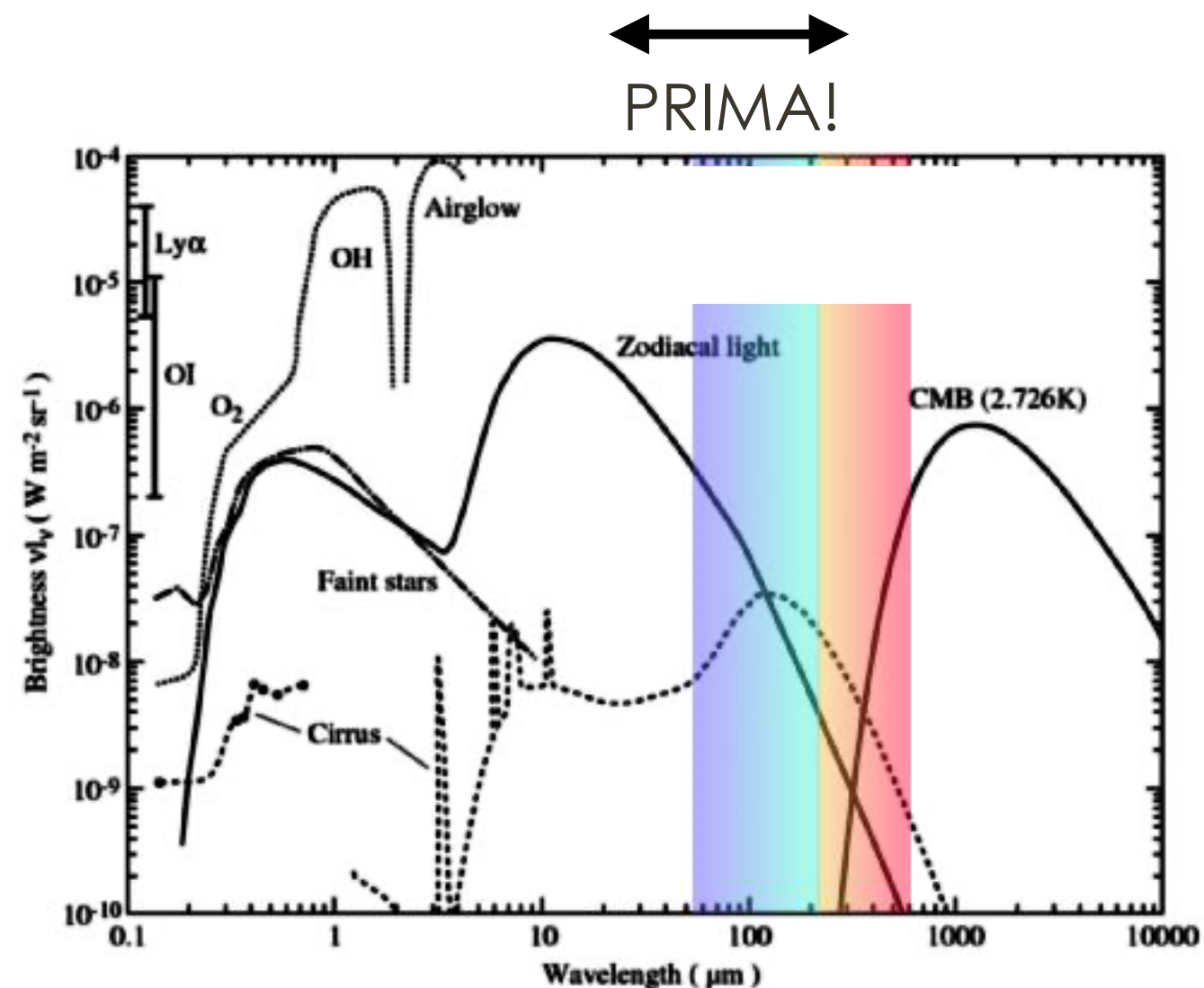
Builds on *decades*
of advanced
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PRIMA in a nutshell

PRIMA has:

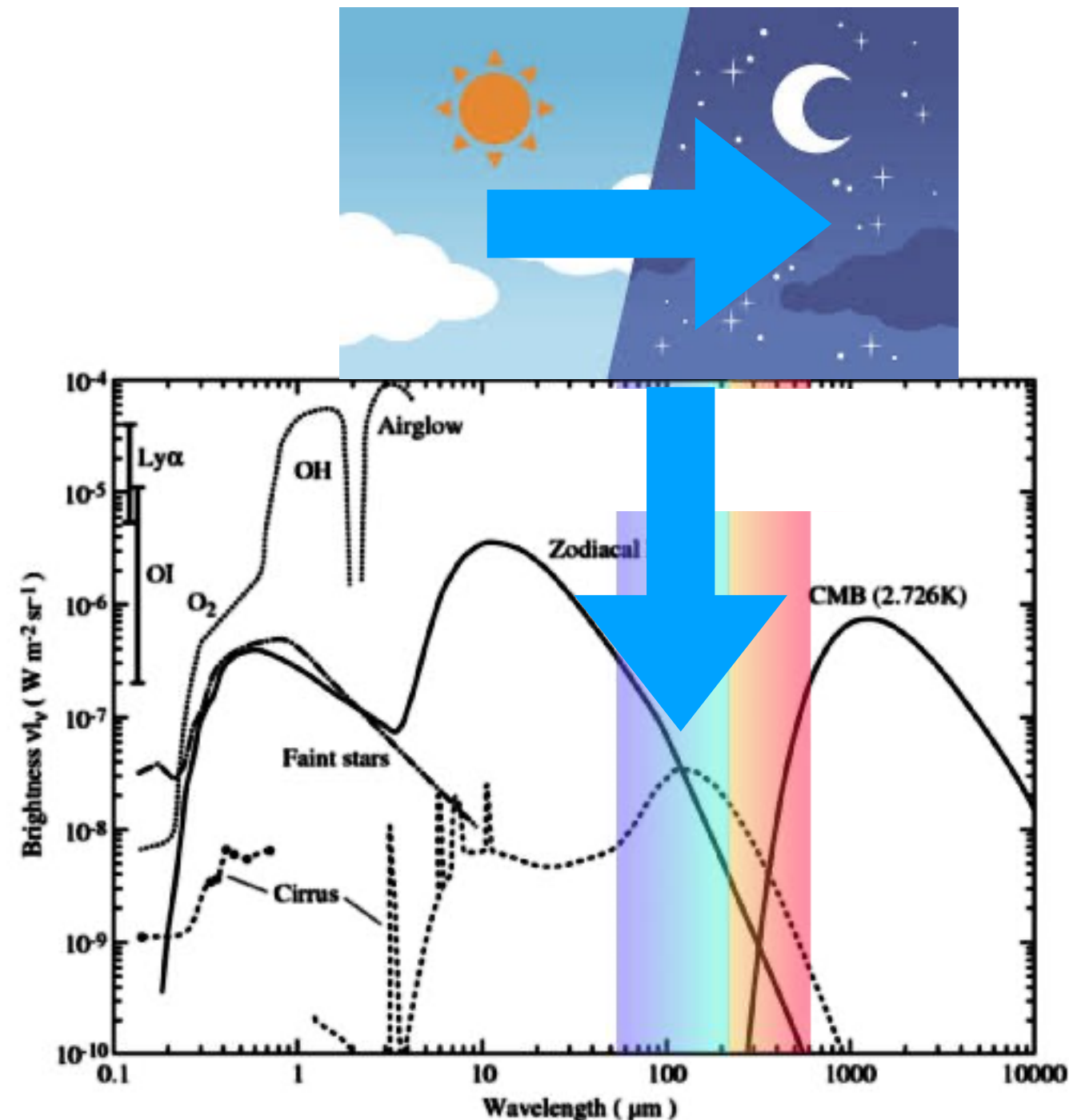
OPPORTUNITY
Space-
background
orders of
magnitude below
prior limits



PRIMA in a nutshell

PRIMA has:

OPPORTUNITY
Space-
background
orders of
magnitude below
prior limits



PRIMA in a nutshell

PRIMA is:

COMPLEMENTARY

Fills the *missing*
wavelength gap
between JWST &
ALMA



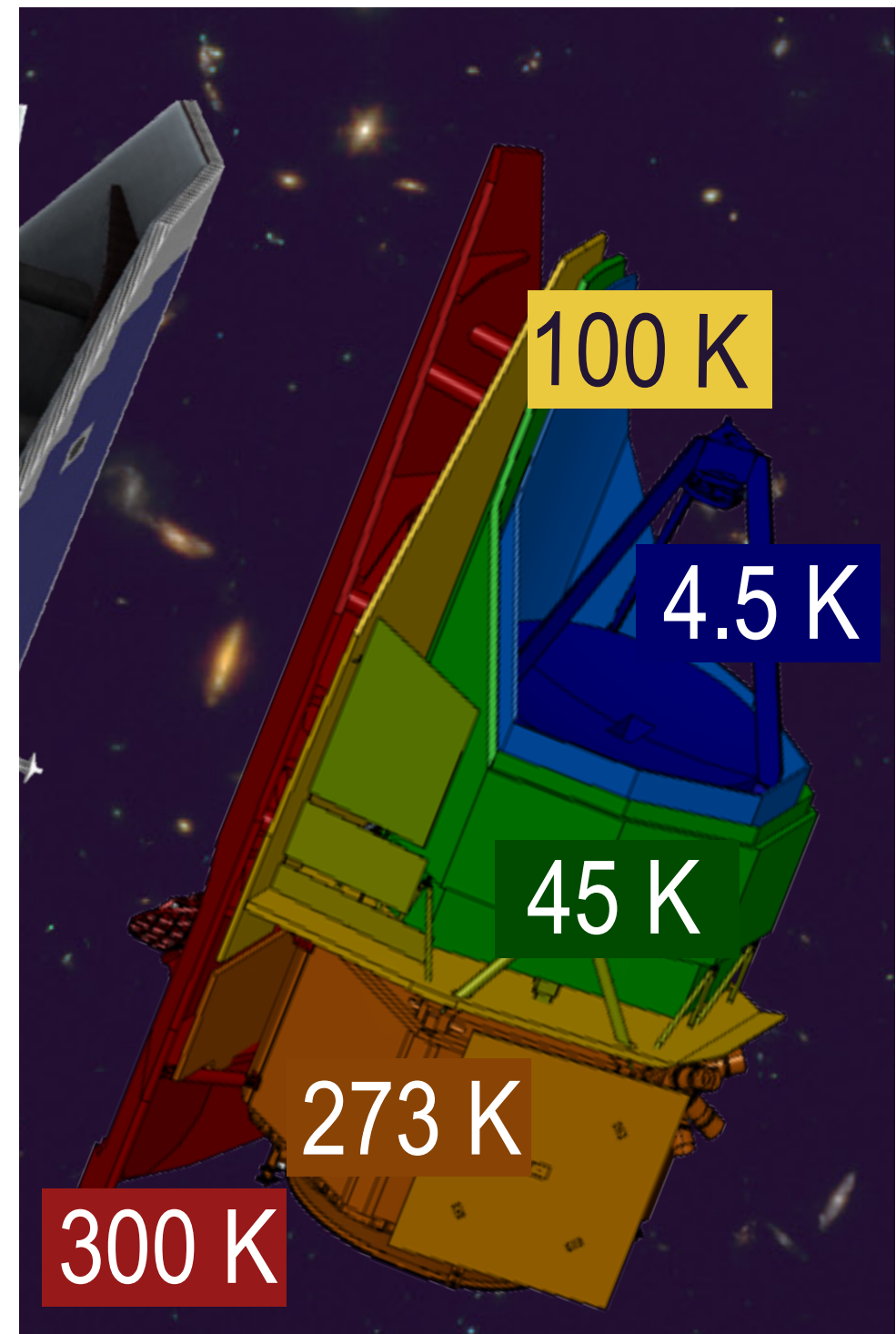
???



PRIMA in a nutshell

PRIMA is:

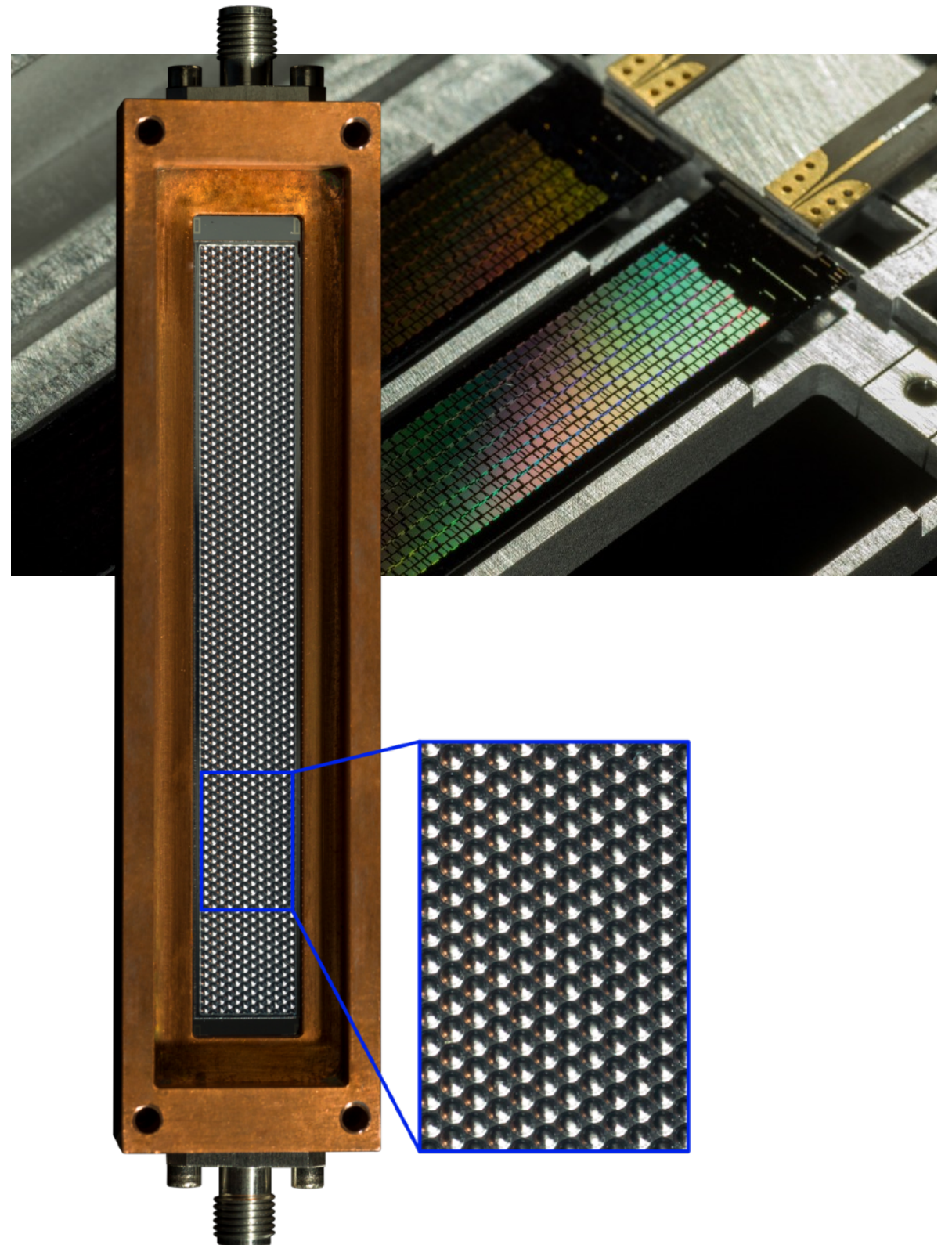
COLD
multistage
passive + active
cooling
4.5K 1.8m primary



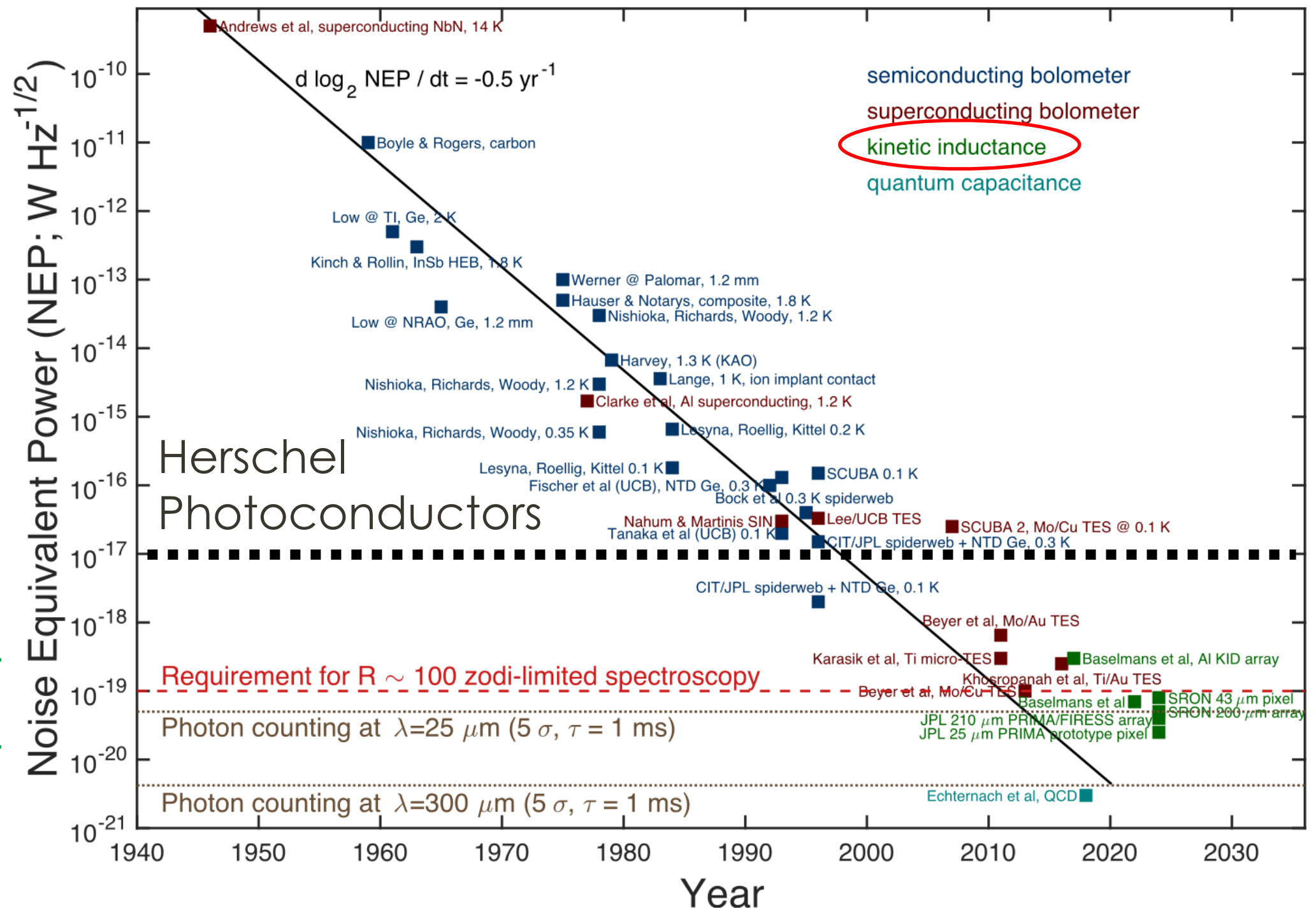
PRIMA in a nutshell

PRIMA is:

ADVANCED
State of the art
large format
quantum KID
detectors



Moore's Law for FIR detectors: Sensitivity doubling every 2 years for 75+ years



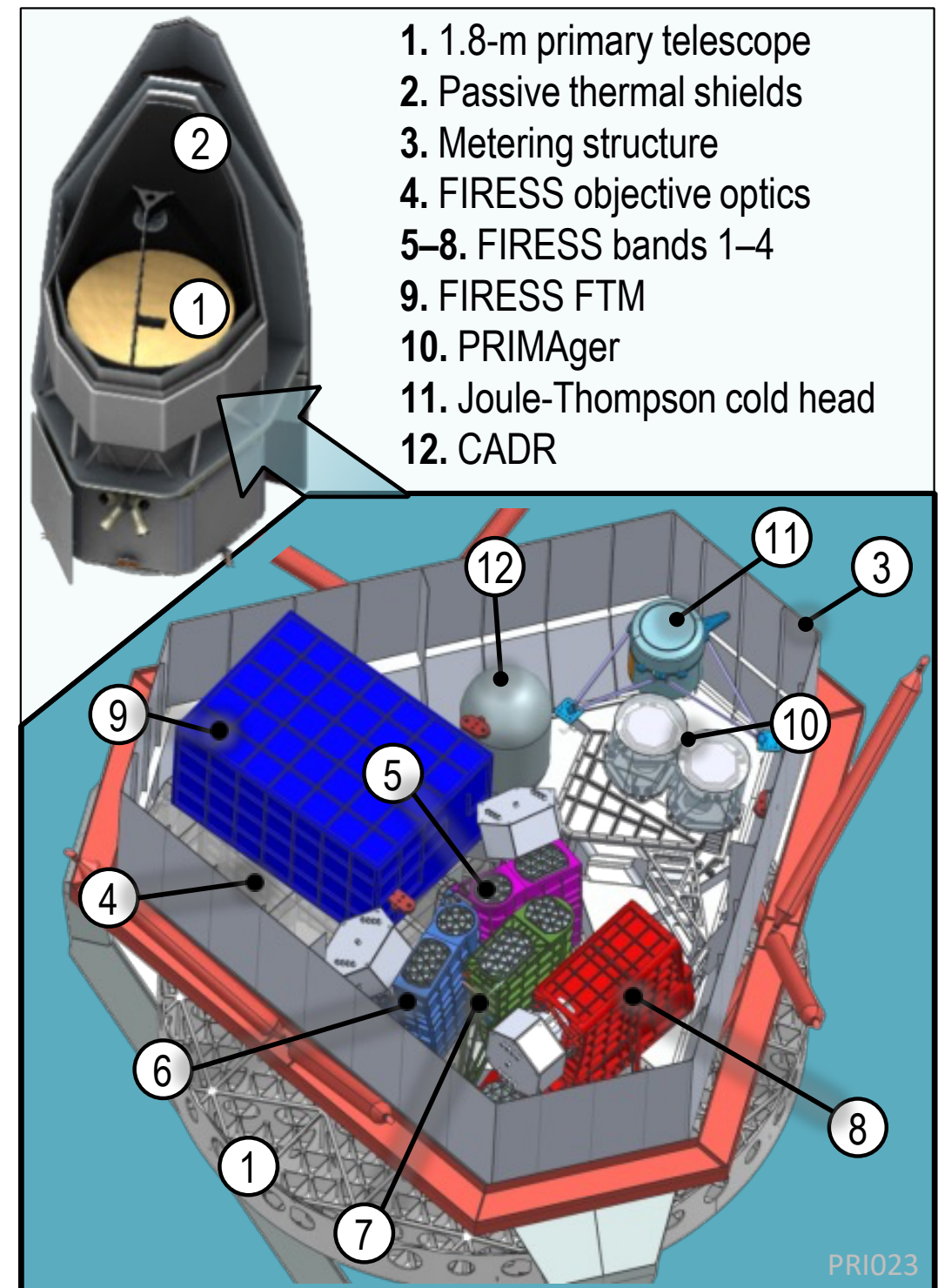
Probe
region of
interest

PRIMA in a nutshell

PRIMA is:

POWERFUL

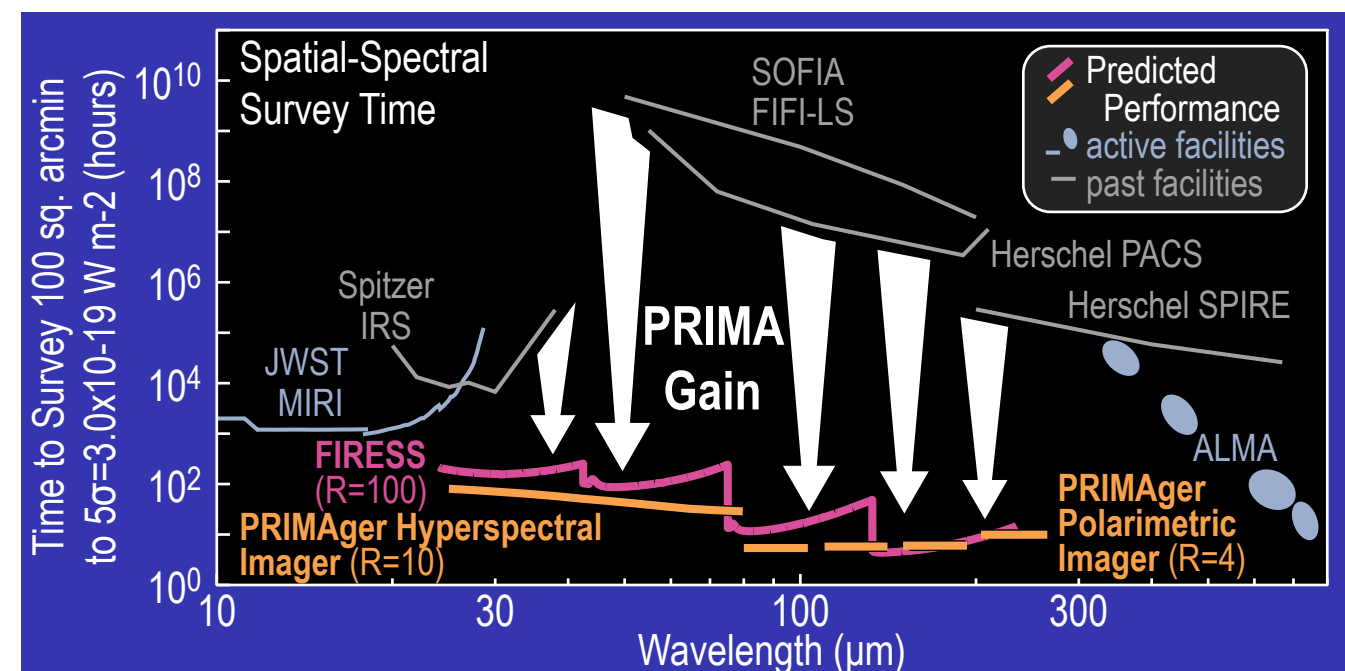
- **PRIMAger Imaging:**
R~10 hyperspectral + polarimetry
- **FIRESS Spectroscopy:**
R~100 up to >10,000
- Full decade in wavelength: **24–261 μm**



PRIMA in a nutshell

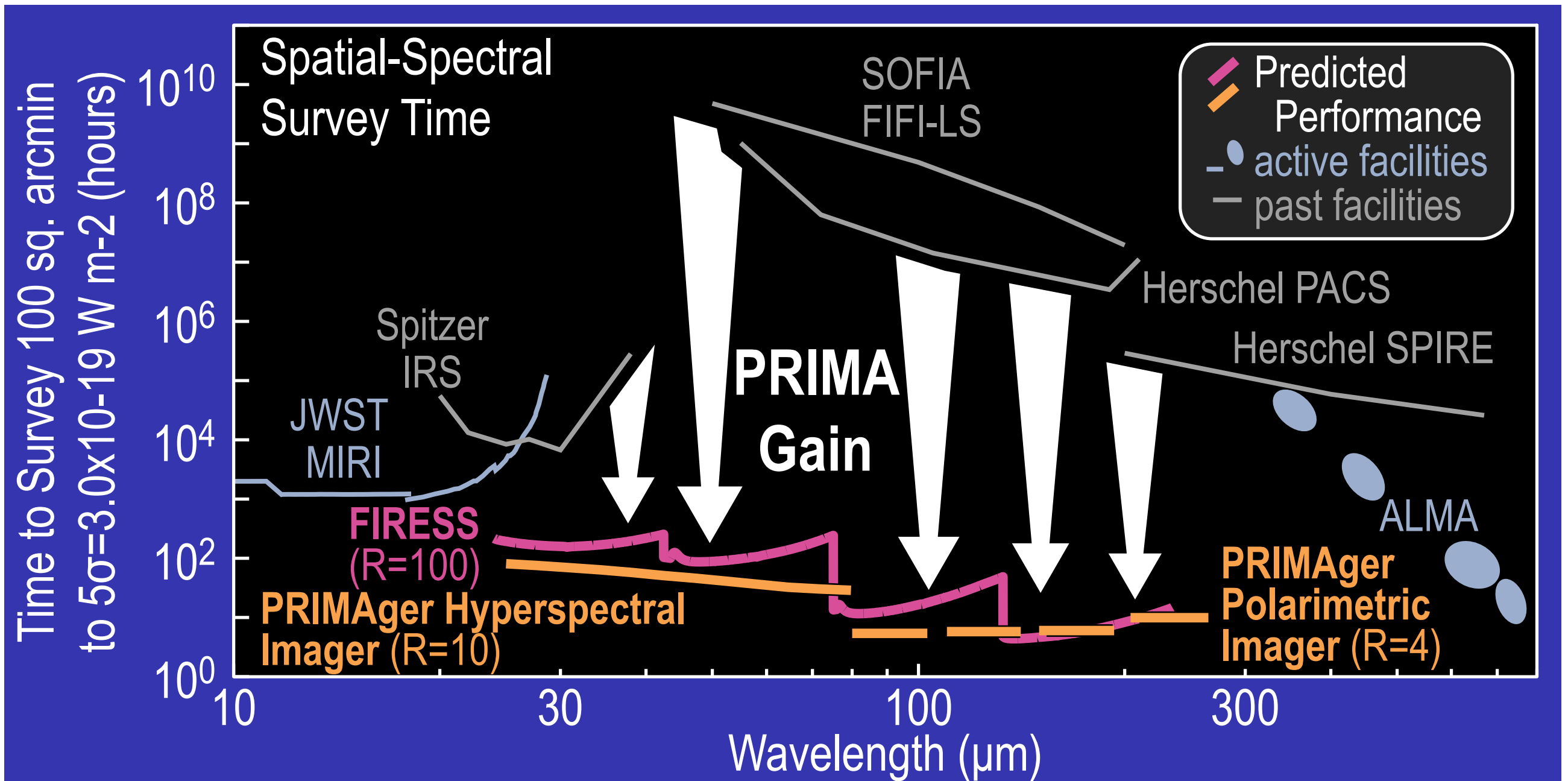
PRIMA is:

SENSITIVE & FAST
>10²x sensitivity
>10⁴x spectral
mapping speed
of Herschel



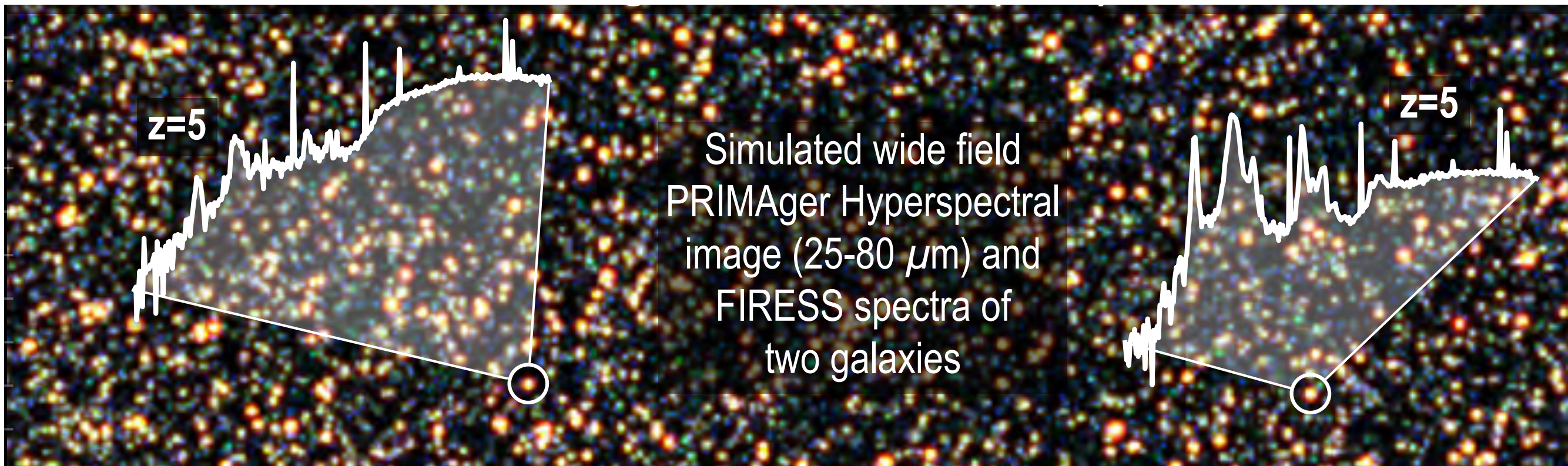


PRIMA in a nutshell



PRIMA's Superpower: *Mapping*

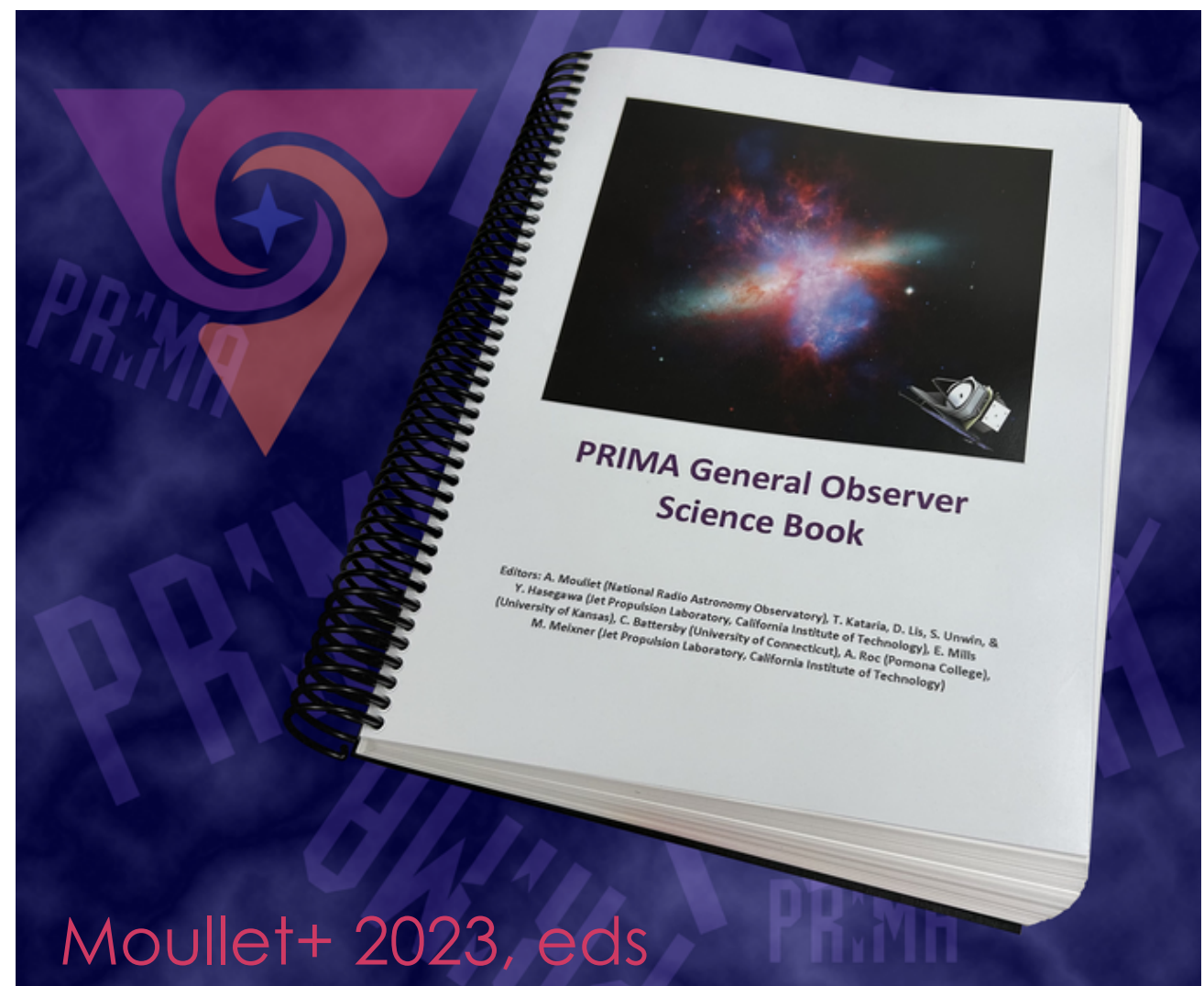
- Fast slew + steering mirror + large FOVs = *very fast mapping* — **PRIMA's superpower**
- Powerful dust and gas **followup** with FIRESS spectroscopy.
- One GO idea: **all-sky survey** @100x Akari/IRAS depth, comparable to Herschel deep fields



PRIMA in a nutshell

PRIMA is:

OPEN
75% of mission
dedicated to GO
science



Moullet+ 2023, eds

PRIMA in a nutshell

PRIMA is:

OPEN
75% of mission
dedicated to GO
science



Moulet+ 2023, eds

PRIMA

Science Book

2nd Edition

Dropping on arXiv *Monday!*

120 new PRIMA
GO Science
Cases

650+ pages!

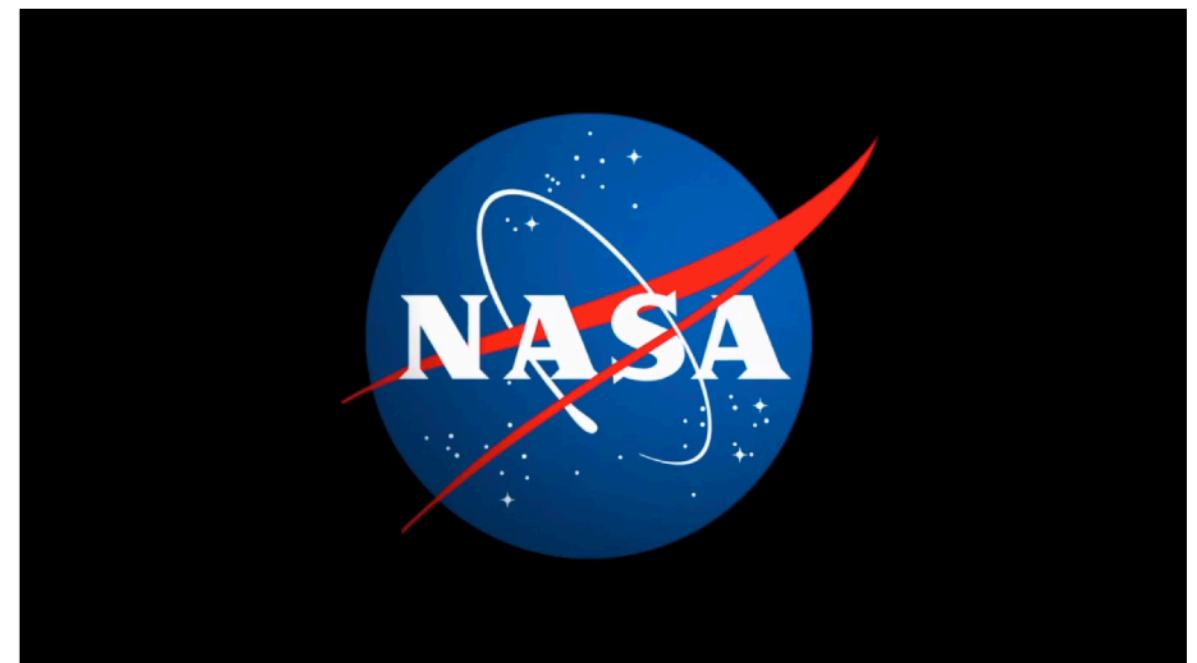


PRIMA General Observer Science Book Volume 2

Editors: A. Moullet (NRAO) , D. Burgarella (Laboratoire d'Astrophysique de Marseille), T. Kataria (Jet Propulsion Laboratory, California Institute of Technology), H. Beuther (Max Planck Institute for Astronomy), C. Battersby (University of Connecticut), T. Essinger-Hileman (NASA Goddard Space Flight Center), H. Inami (Hiroshima University), E. Mills (University of Kansas), T. Nagao (Ehime University), S. Unwin (Jet Propulsion Laboratory, California Institute of Technology)
(Eds.)

PRIMA Origins and Key Science

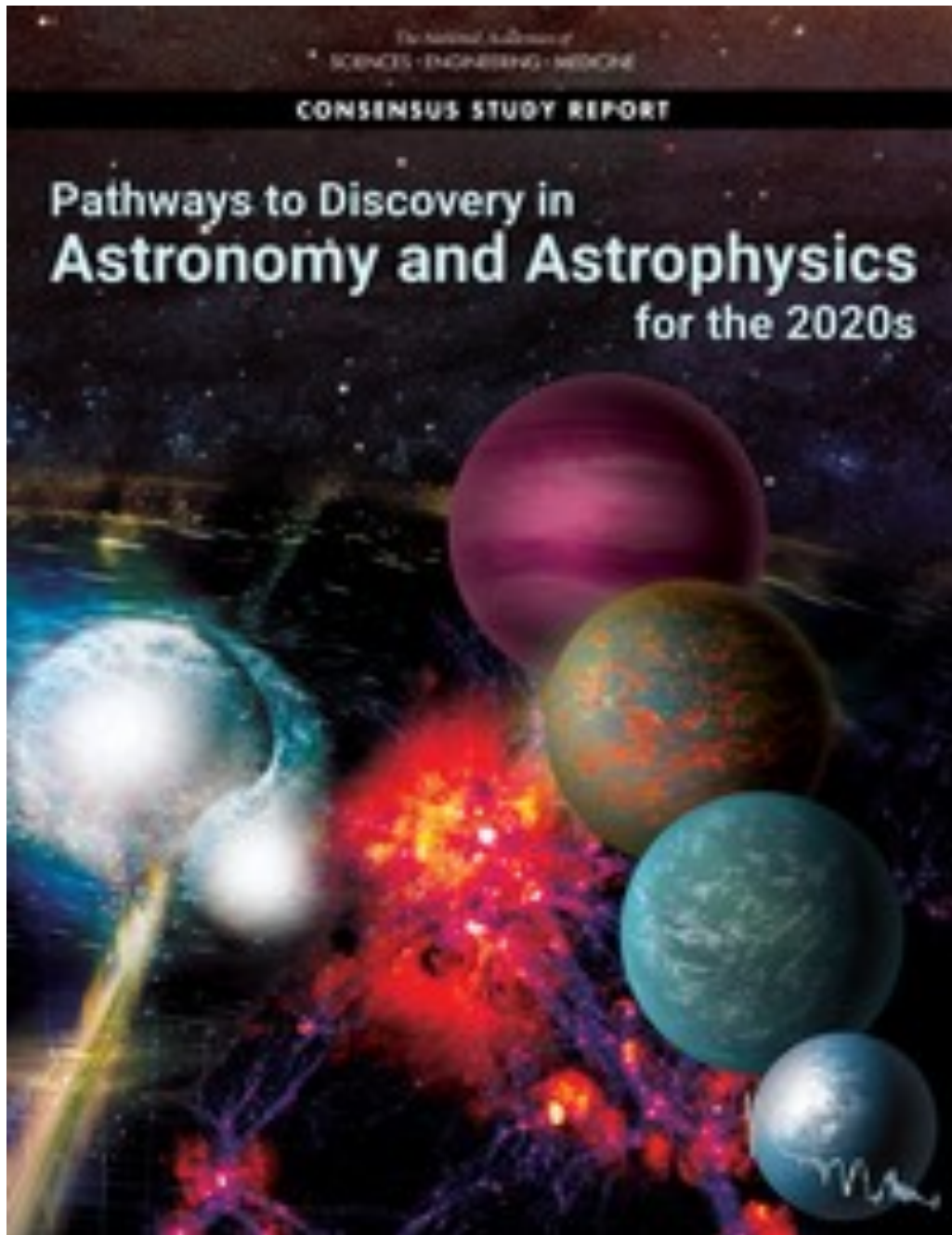
NASA Establishes New Class of Astrophysics Missions, Selects Studies



Credit: NASA

“Probe Explorers” <\$1B

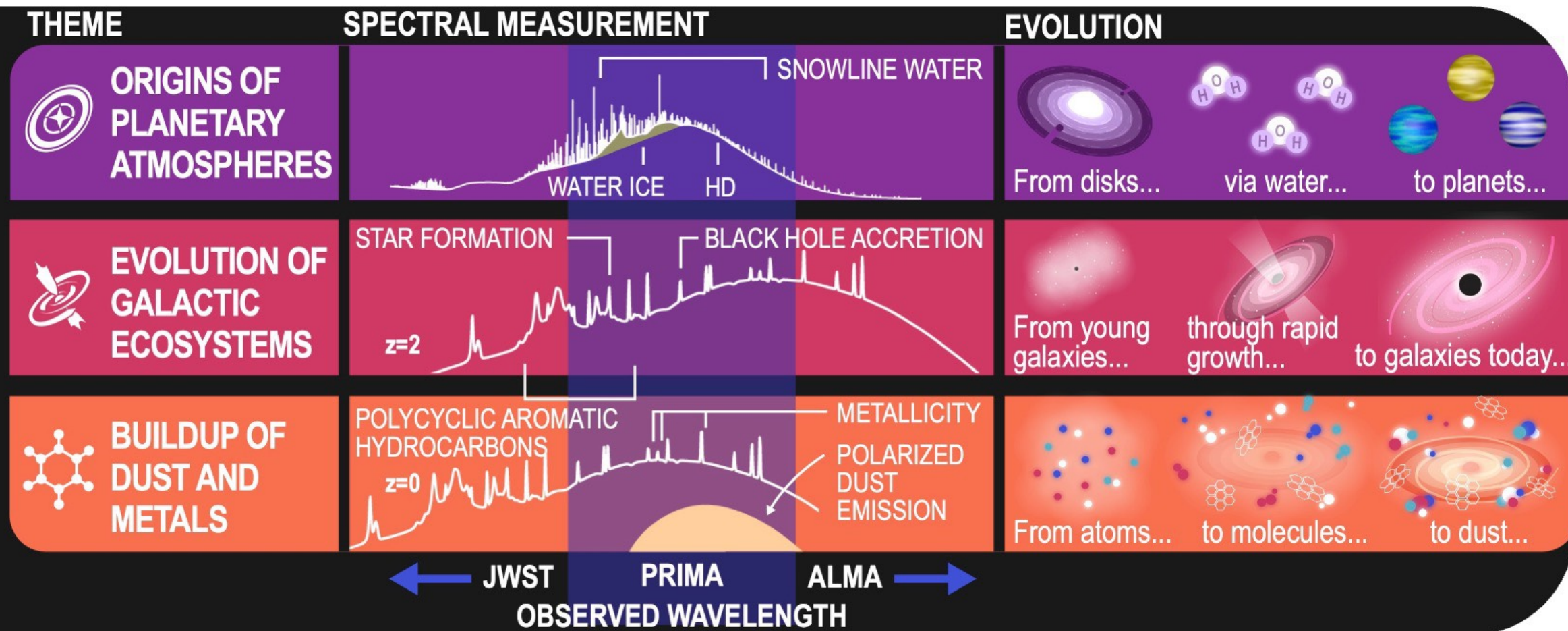
and a probe scale mission is an extremely timely and compelling opportunity to do so. These scientific areas include tracing the astrochemical signatures of planet formation (within and outside of our own Solar System), measuring the formation and buildup of galaxies, heavy elements, and interstellar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



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



PRIMA Dust

1. What is the origin of dust in the Universe today?
Stardust? ISM dust?
2. How have dust and metals co-evolved over the past
10 billion years?
3. When and where did the first carbon nanoparticles
emerge in the Universe?

From the Community: Across the Peak

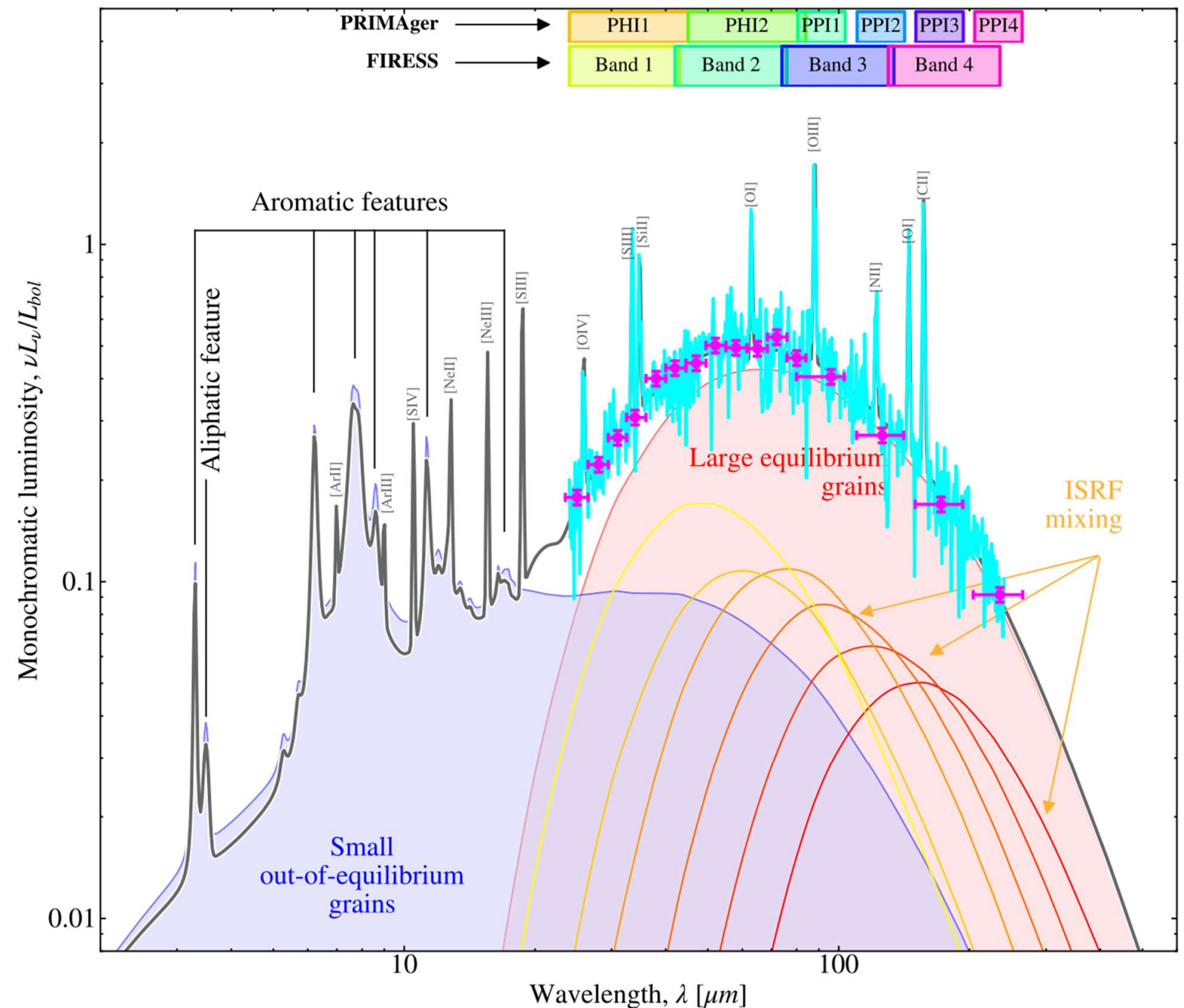
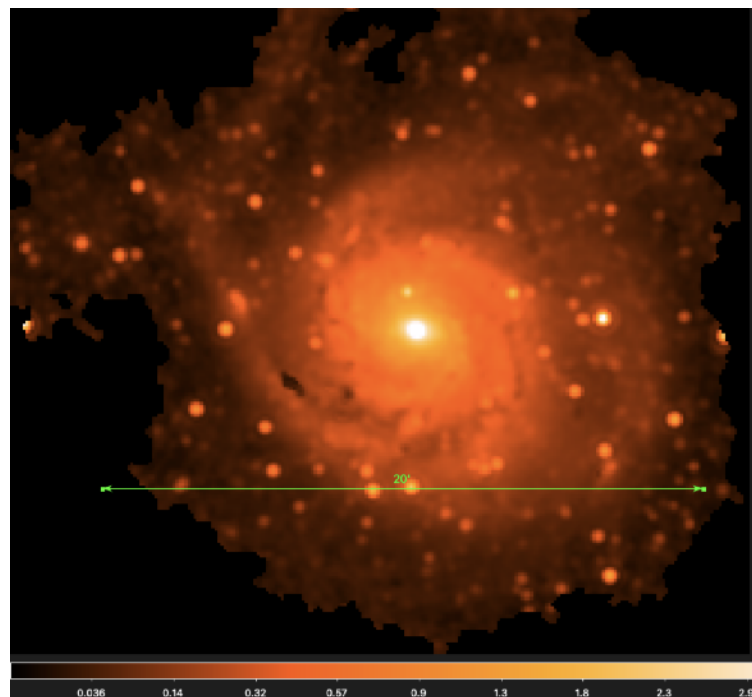
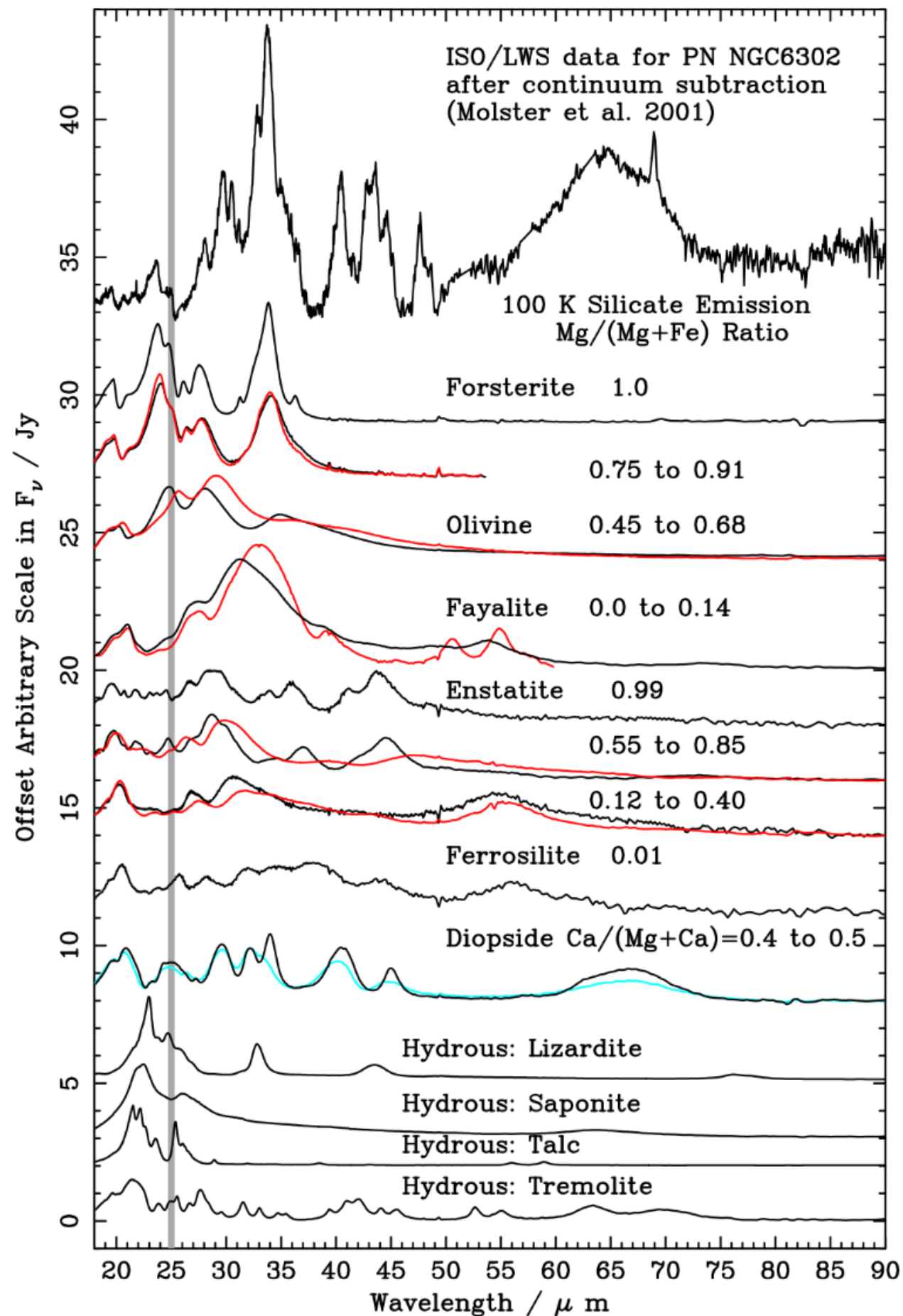


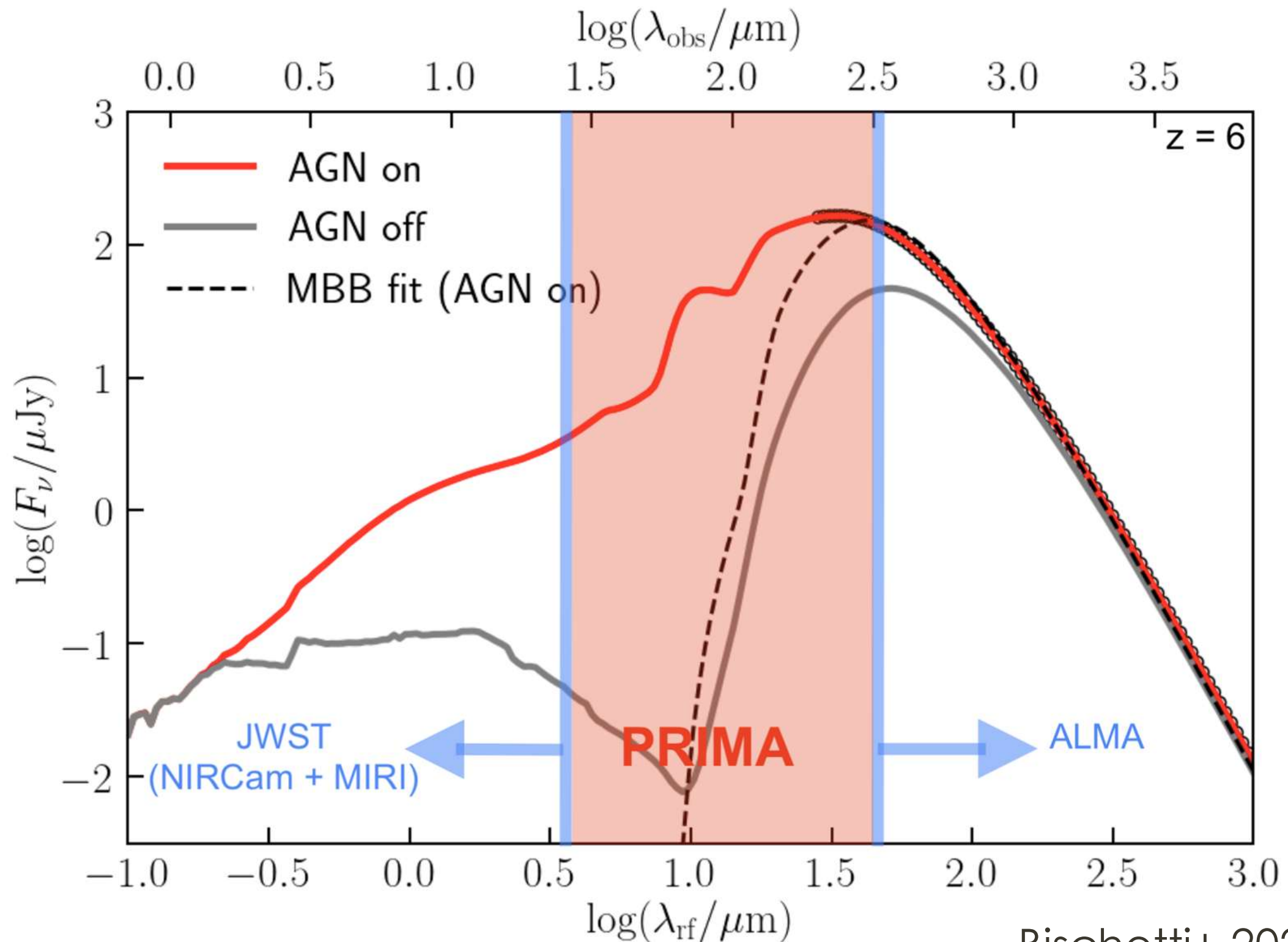
Figure 1. Typical SED of a star-forming region with the brightest gas lines. The magenta error bars correspond to broad-band spectrophotometry with $R \approx 3.5$ (10σ), and the cyan line is a $R \approx 200$ spectrum (5σ)



From the Community: Mineralogy

Bower; Kemper; Galliano
2023/2025, GOB1+2

From the community: Dust Heating in $z > 5$ AGN



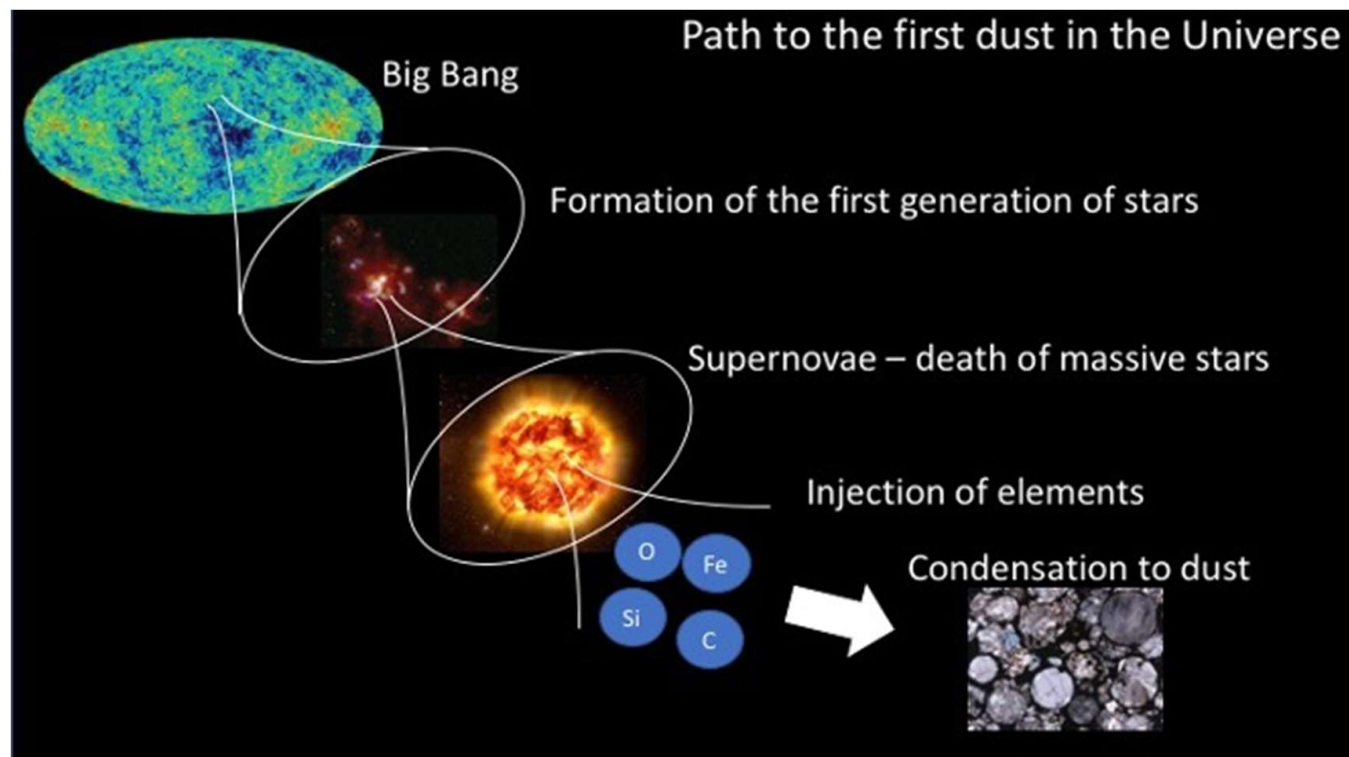


Figure 1. The pathway to form the first dust in the universe: after the Big Bang, the first generation of stars are formed, and high mass stars die as supernovae. These SNe synthesize elements, and some of refractory elements condense into dust grains.

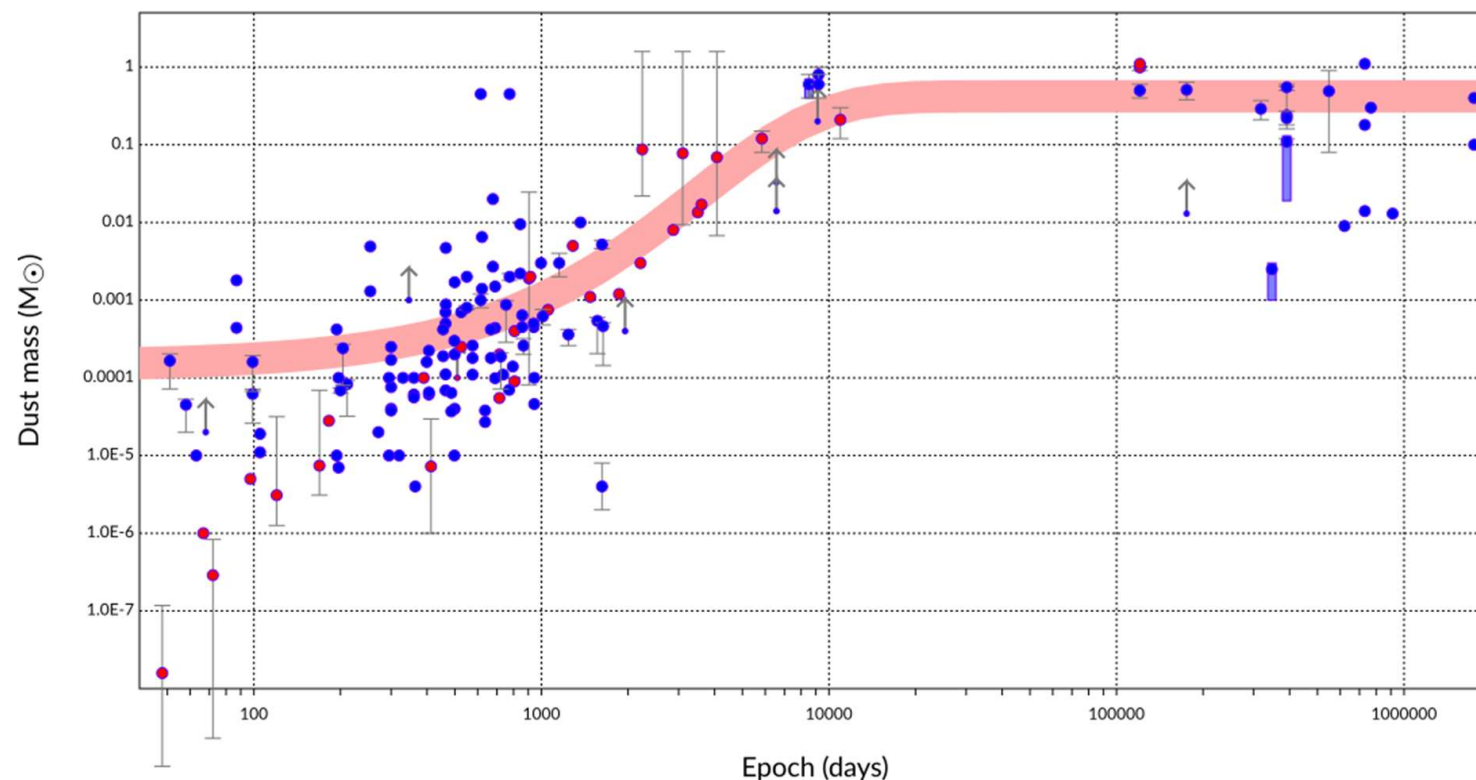


Figure 2. Dust masses measured in SNe, as a function of epoch since the SN explosion (Revised from Niculescu-Duvaz et al. 2022; <https://nebulousresearch.org/dustmasses/>)

**From the community:
How much dust
production in SNe??**



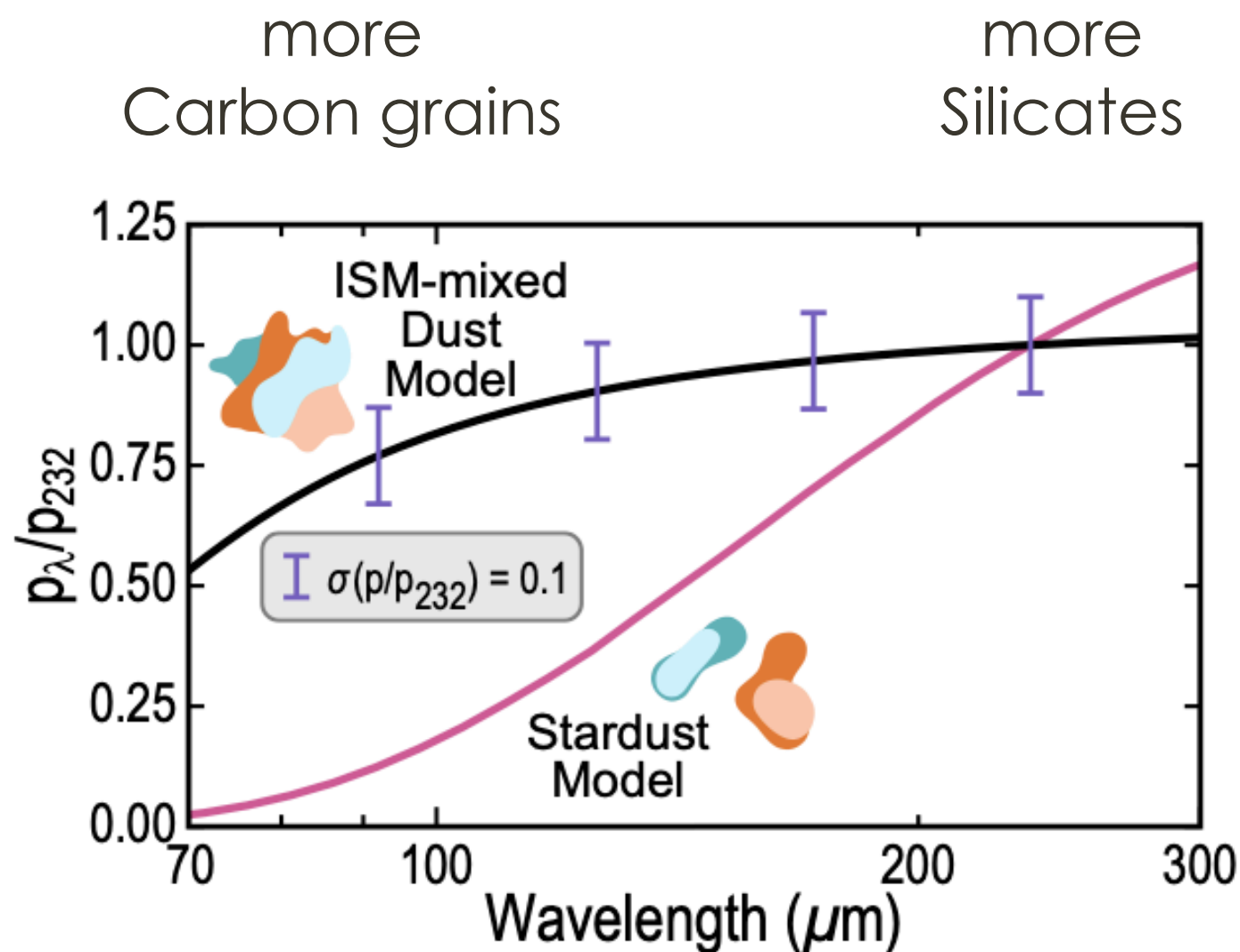
Matsuura 25, GOB2



Interstellar Dust Grain Structure and Origins

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

- **Polarization holds the key** to understanding the origin of dust grains.
- **Polarization SED should rise sharply with wavelength** if C & Si populations *remain* separated.
- PRIMA will **directly test** ISM **grain growth** and see if it is suppressed at low-metallicity by **polarization imaging** of local galaxies (**91-232 μm**).

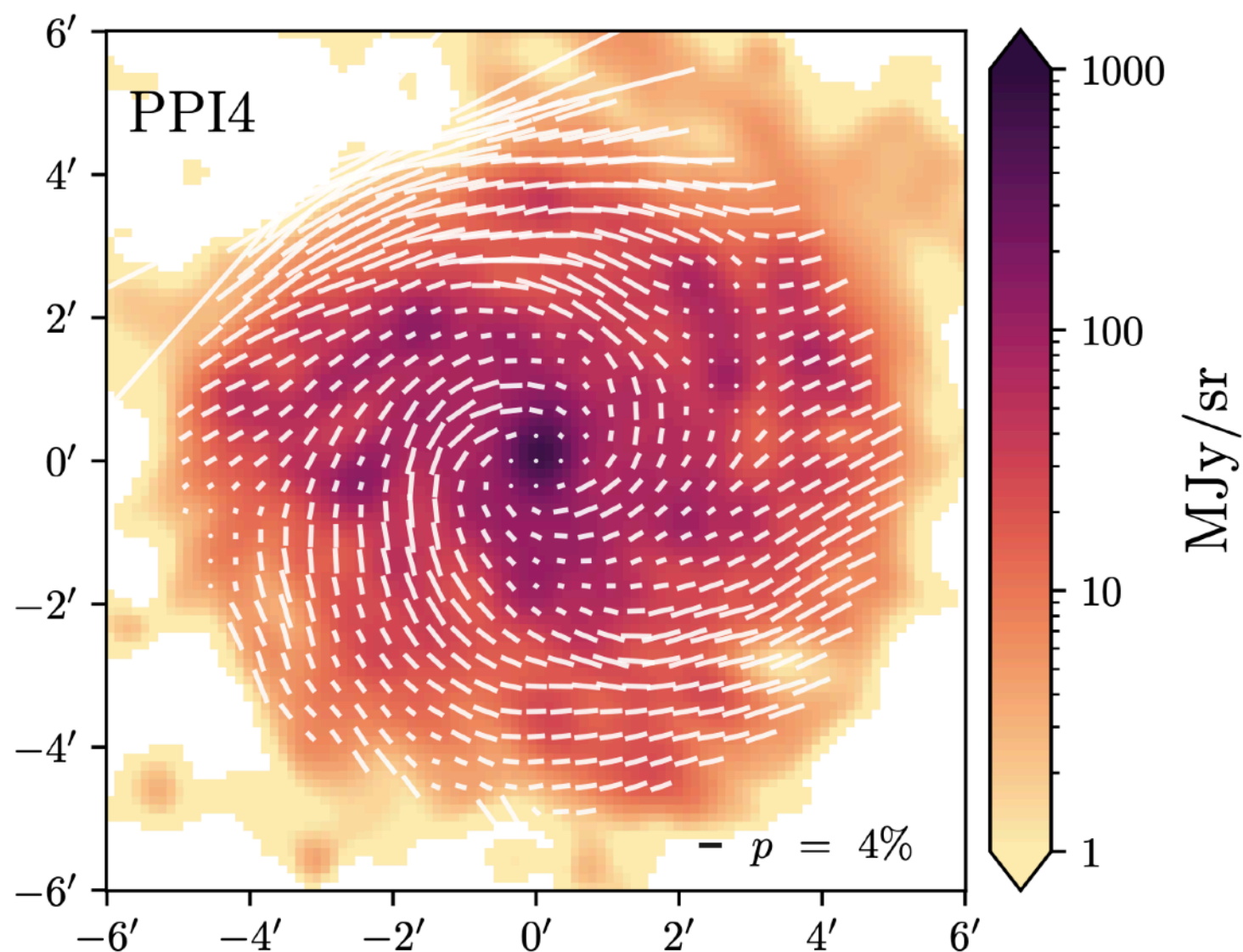
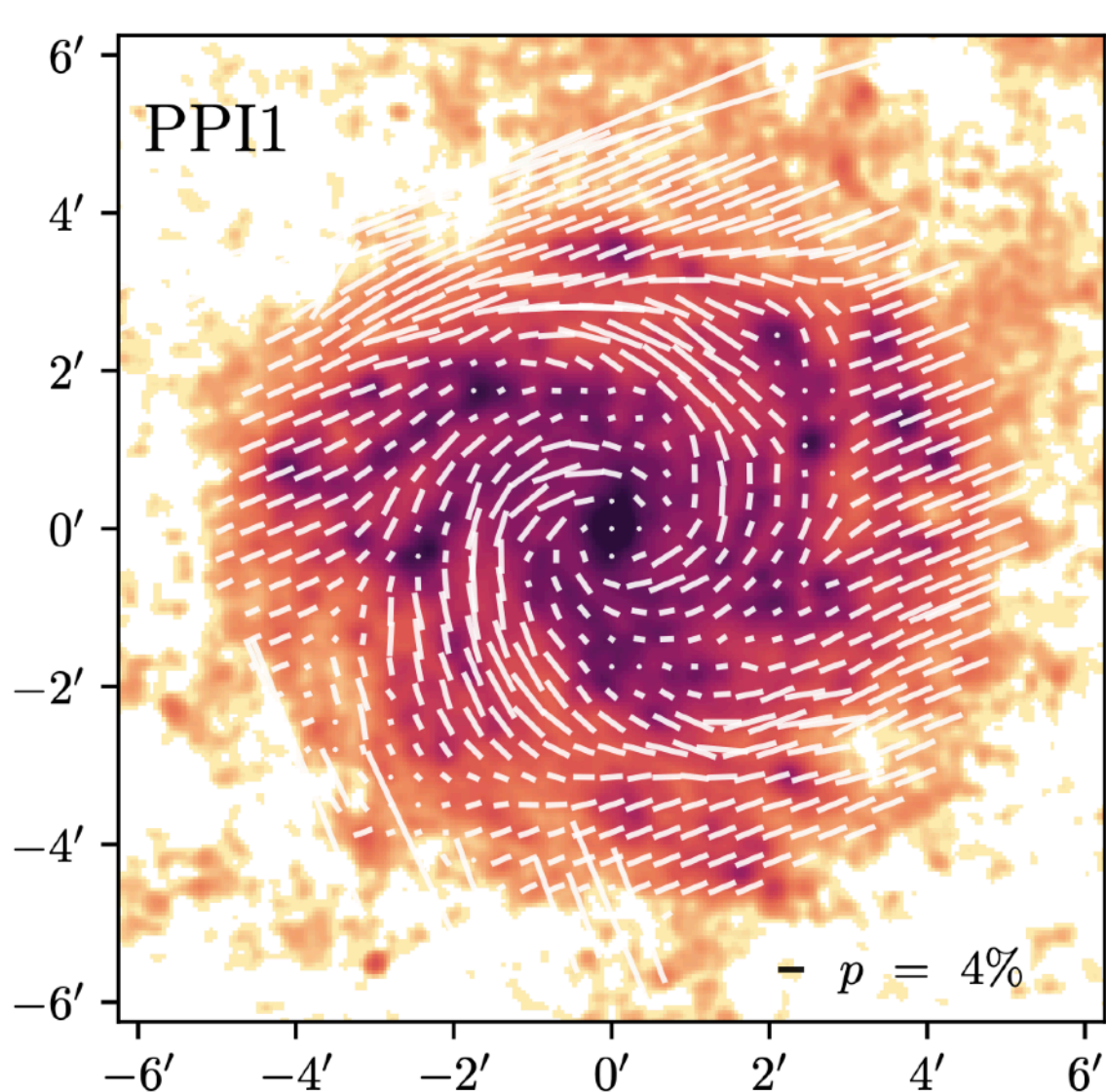


see Hensley+Draine 2023



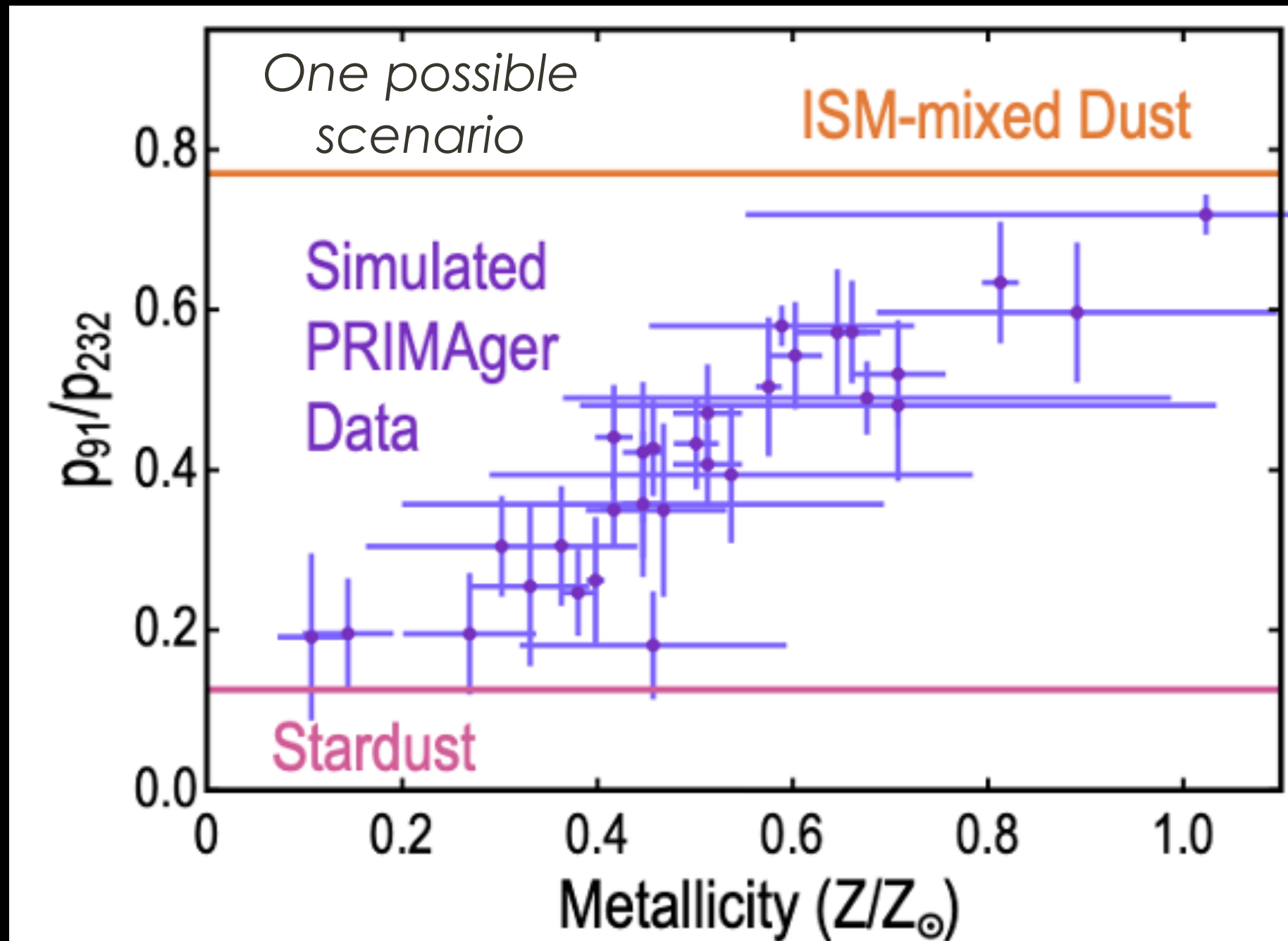
BUILDUP OF DUST AND METALS

- If Herschel could measure dust *emission*, PRIMA can measure its *polarization* ($p > 2\%$)! Dowell, BH, & Sauvage 2024





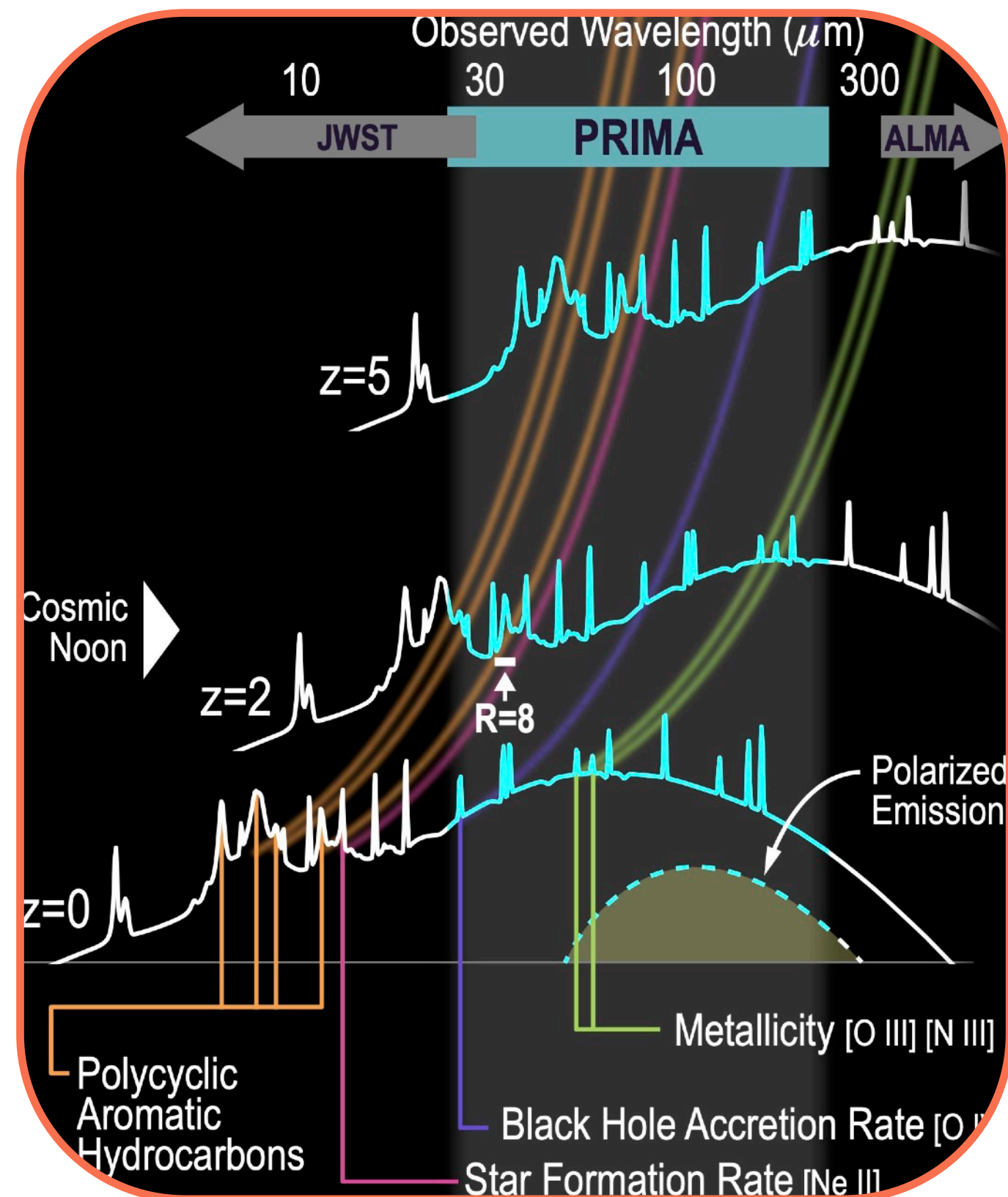
BUILDUP OF DUST AND METALS





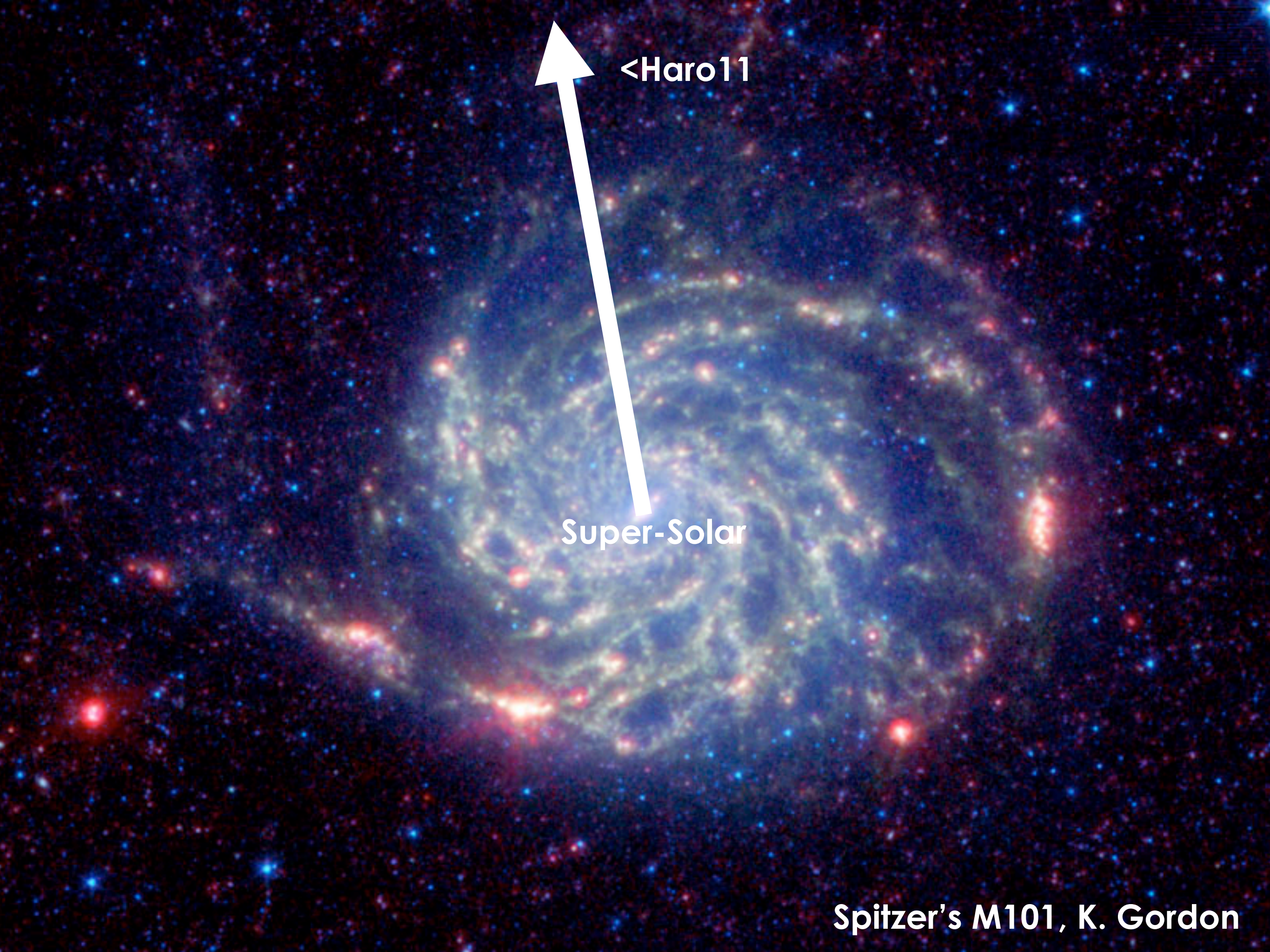
How have dust and metals co-evolved over the past 10 billion years?

- Hyper-spectral imaging + FIR spectra and provide crucial diagnostics of:
- Dust emission in the form resolved **PAHs**
- Temperature-insensitive metal-sensitive fine structure lines
 $[NIII]/[OIII] = \mathbf{N3O3}$





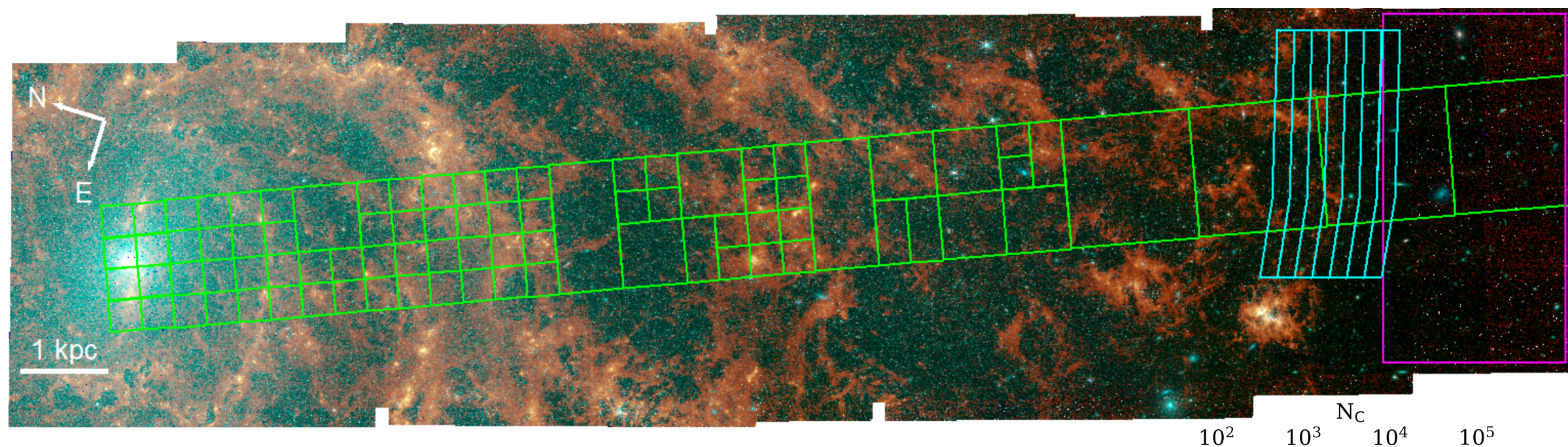
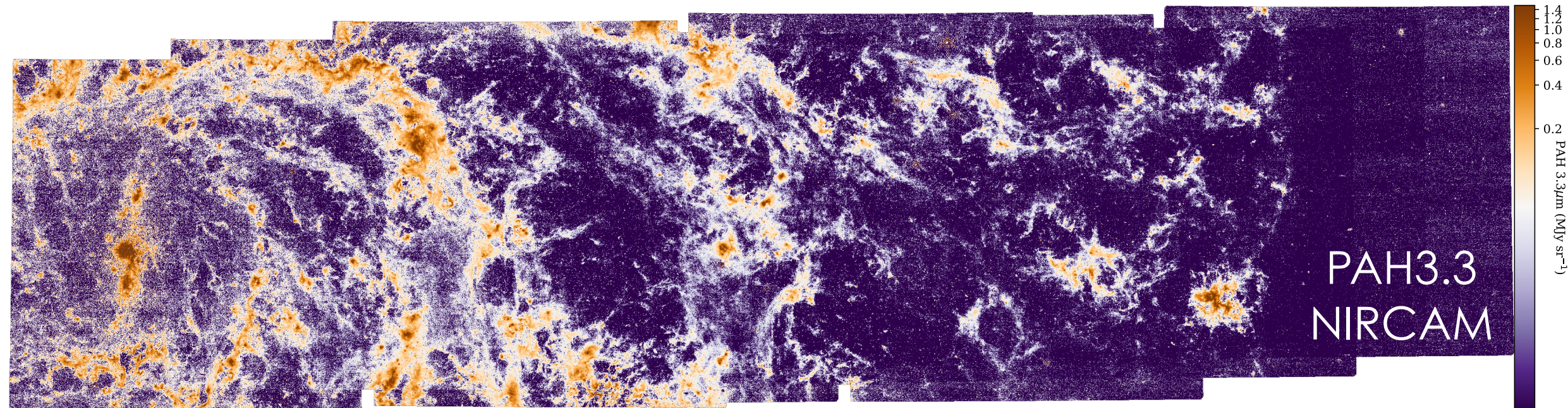
Spitzer's M101, K. Gordon



<Haro11

Super-Solar

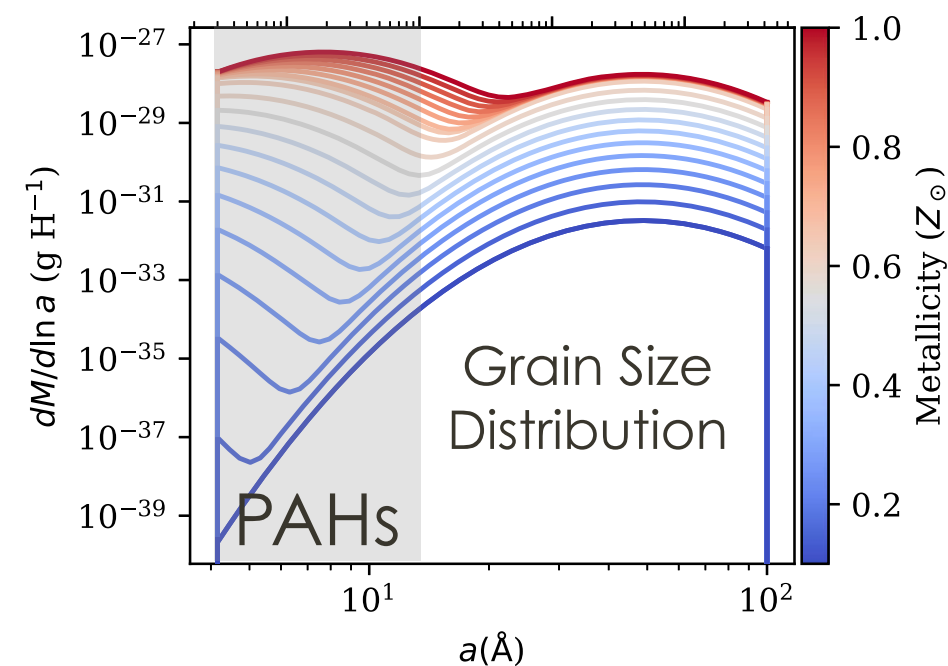
Spitzer's M101, K. Gordon

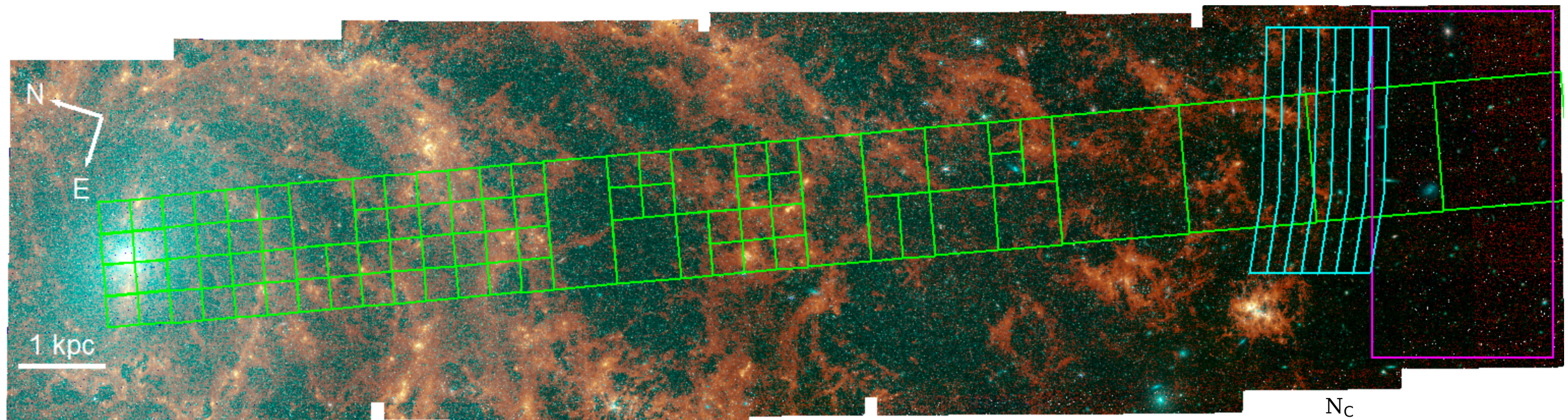
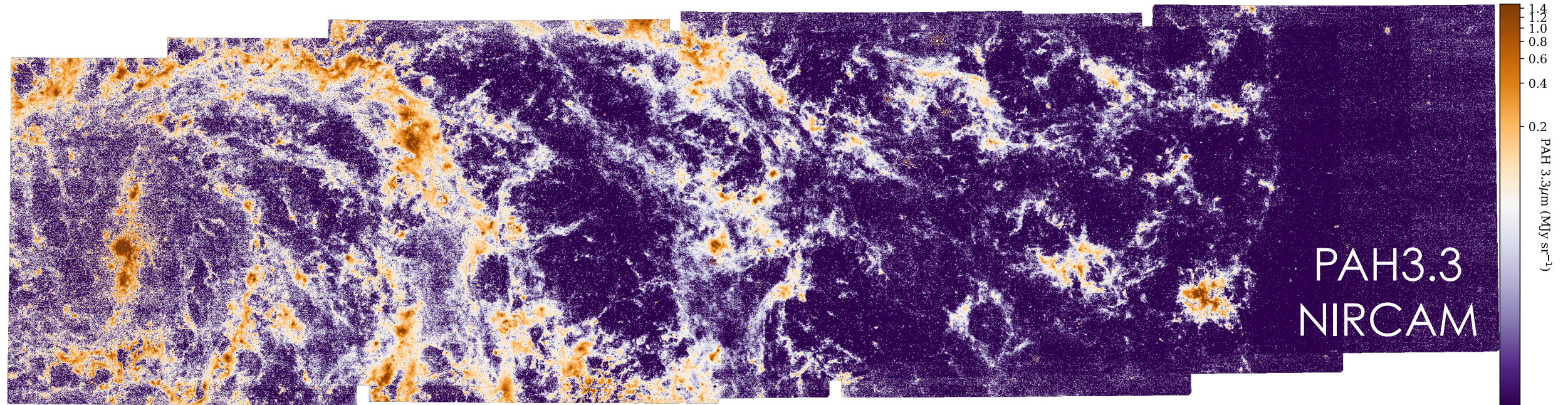


Cory Whitcomb+ 2024, 2025



See also
posters/talks by
Tarantino, Lai,
Chown,
Sandstrom ...



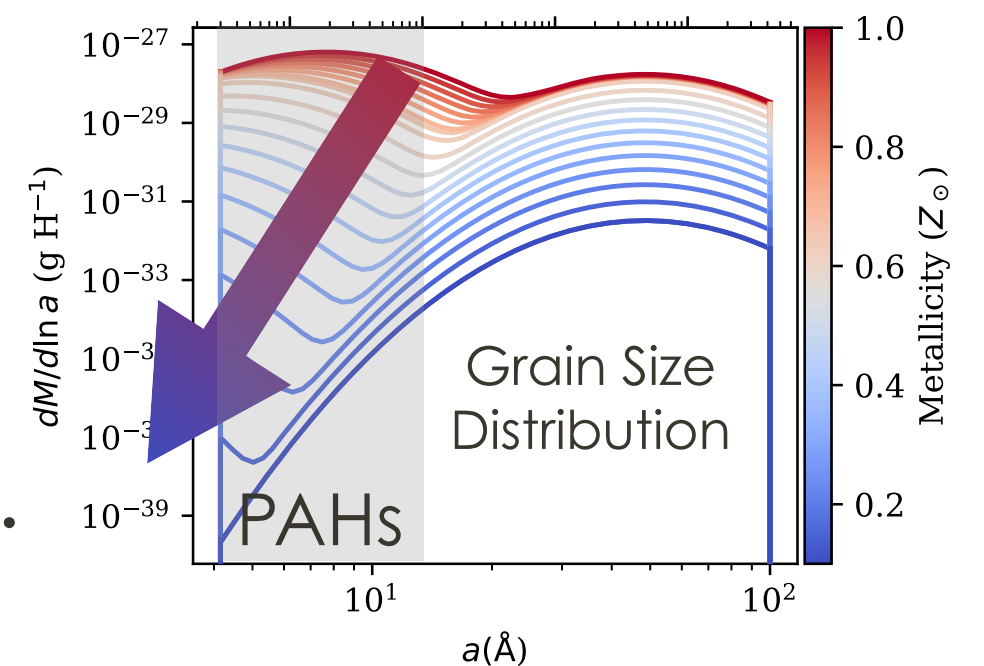


Cory Whitcomb+ 2024, 2025

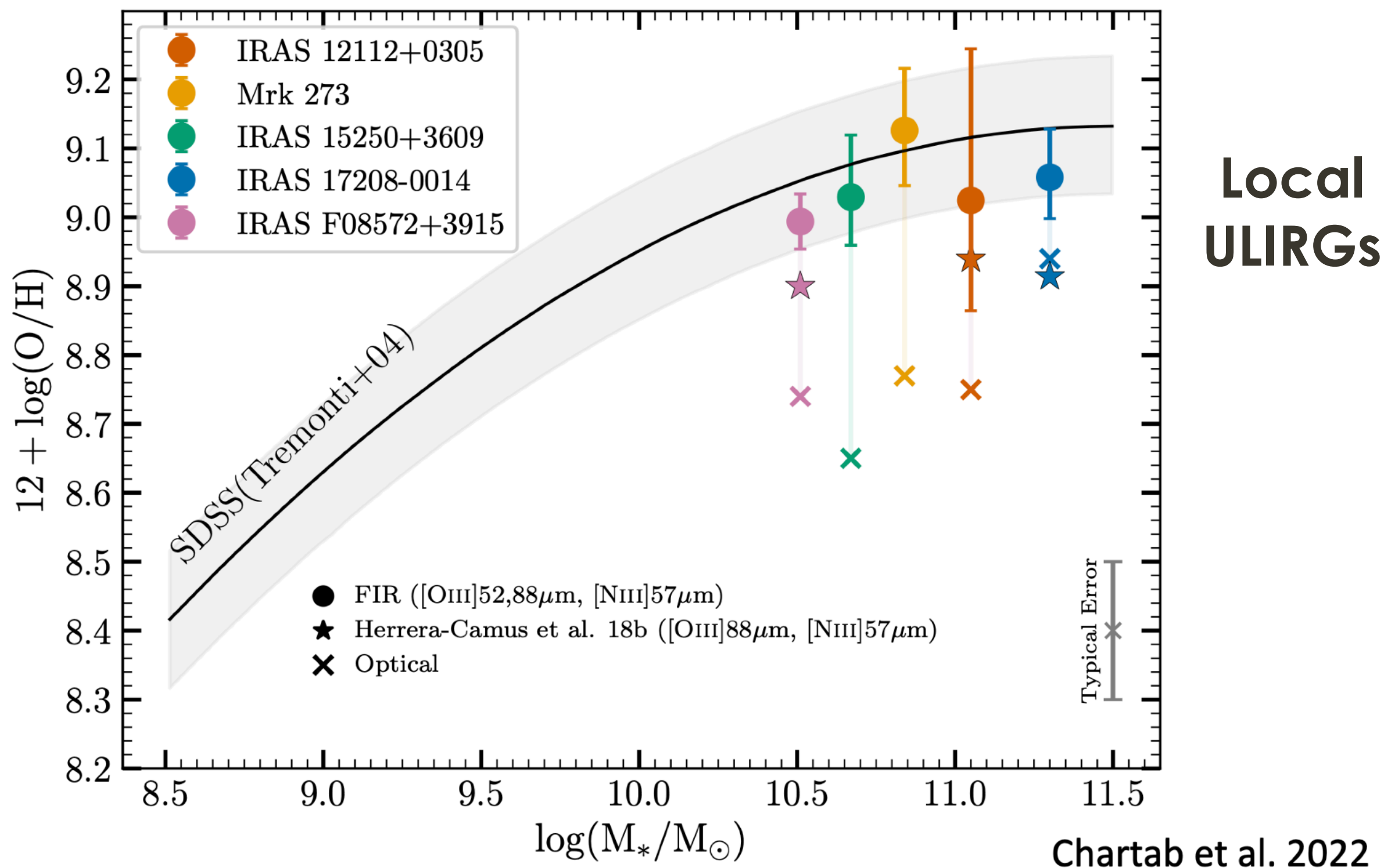


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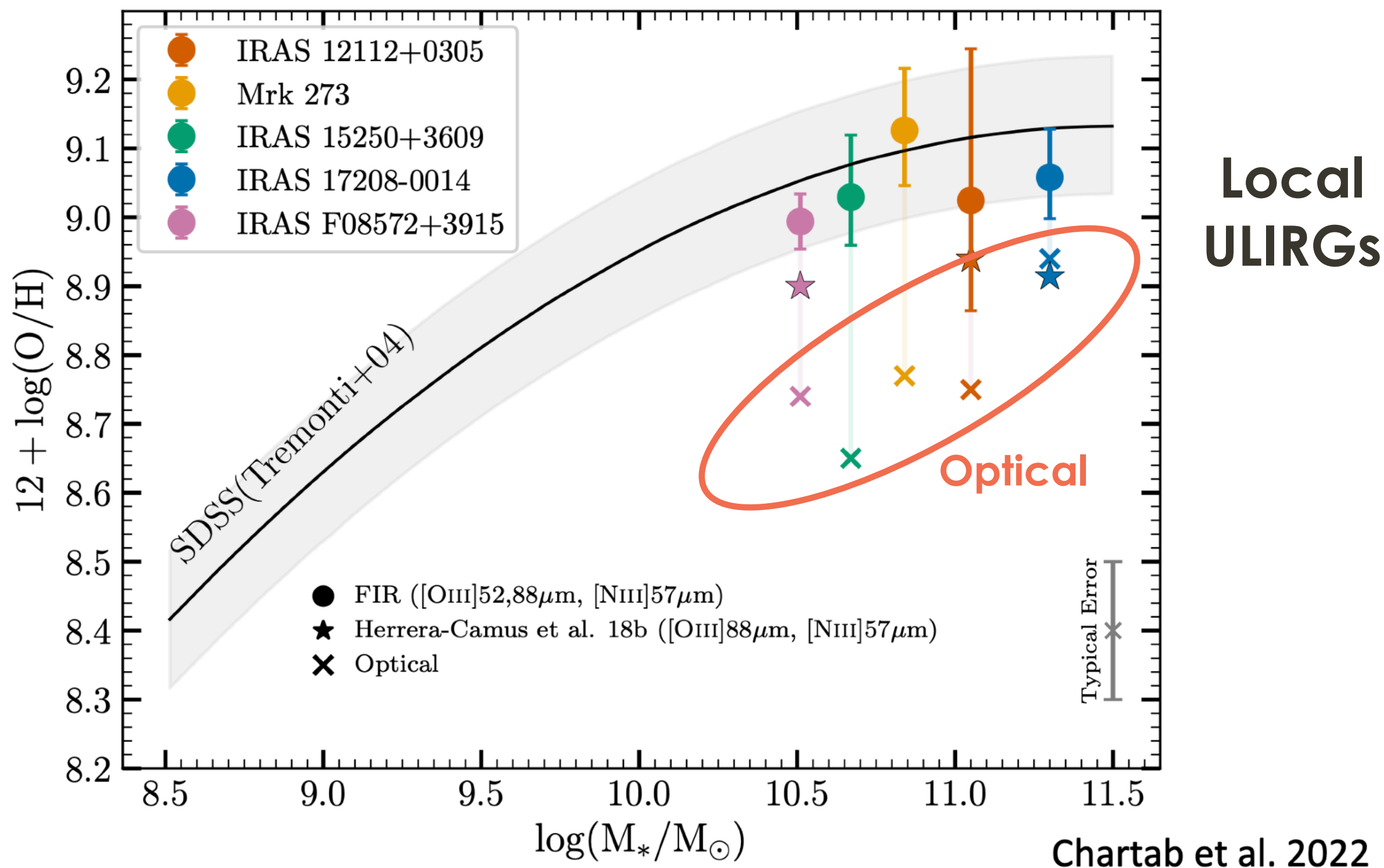
**Grains get
smaller as
metallicity
declines...
inhibited growth.**



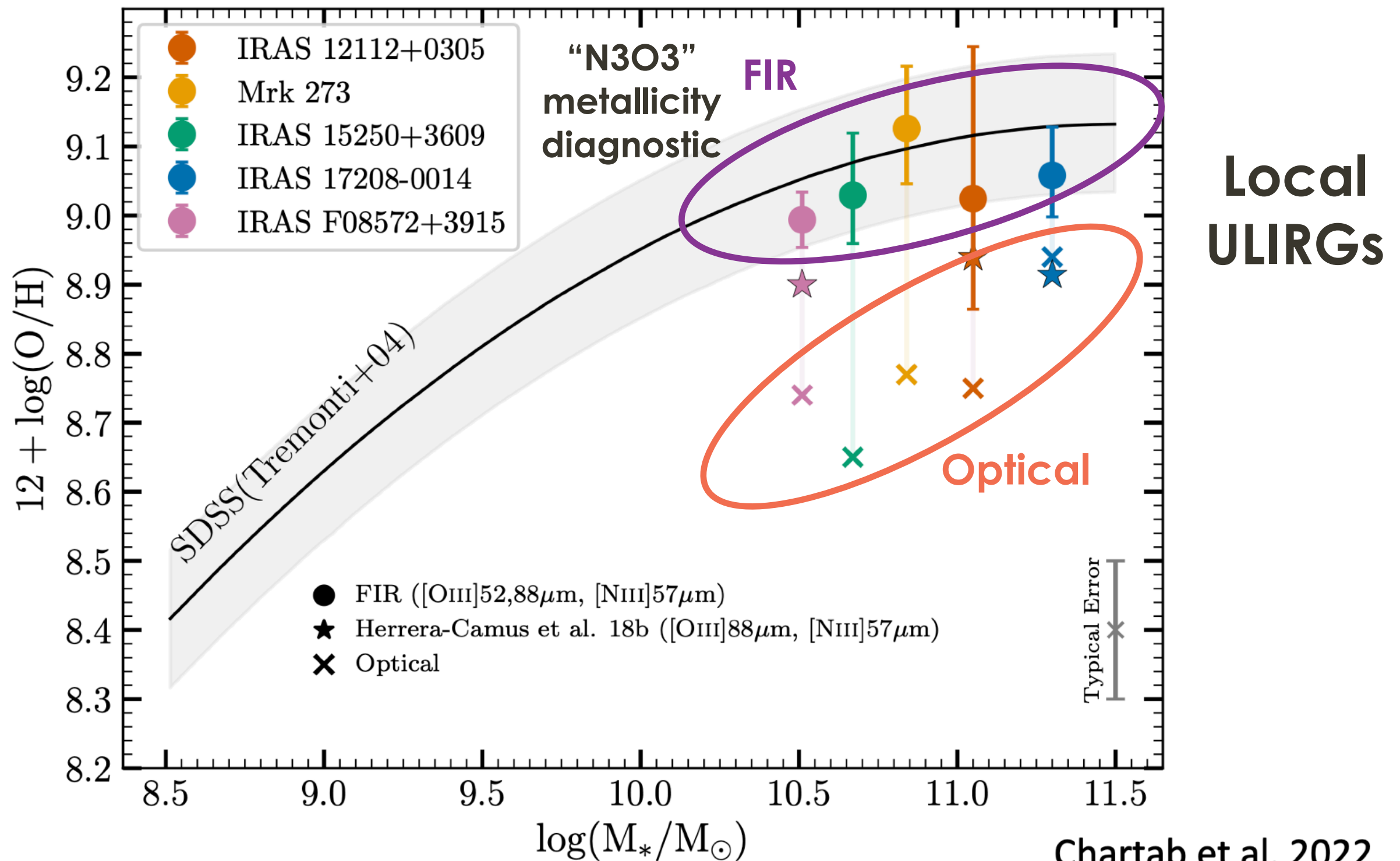
Far-Infrared Metallicity



Far-Infrared Metallicity



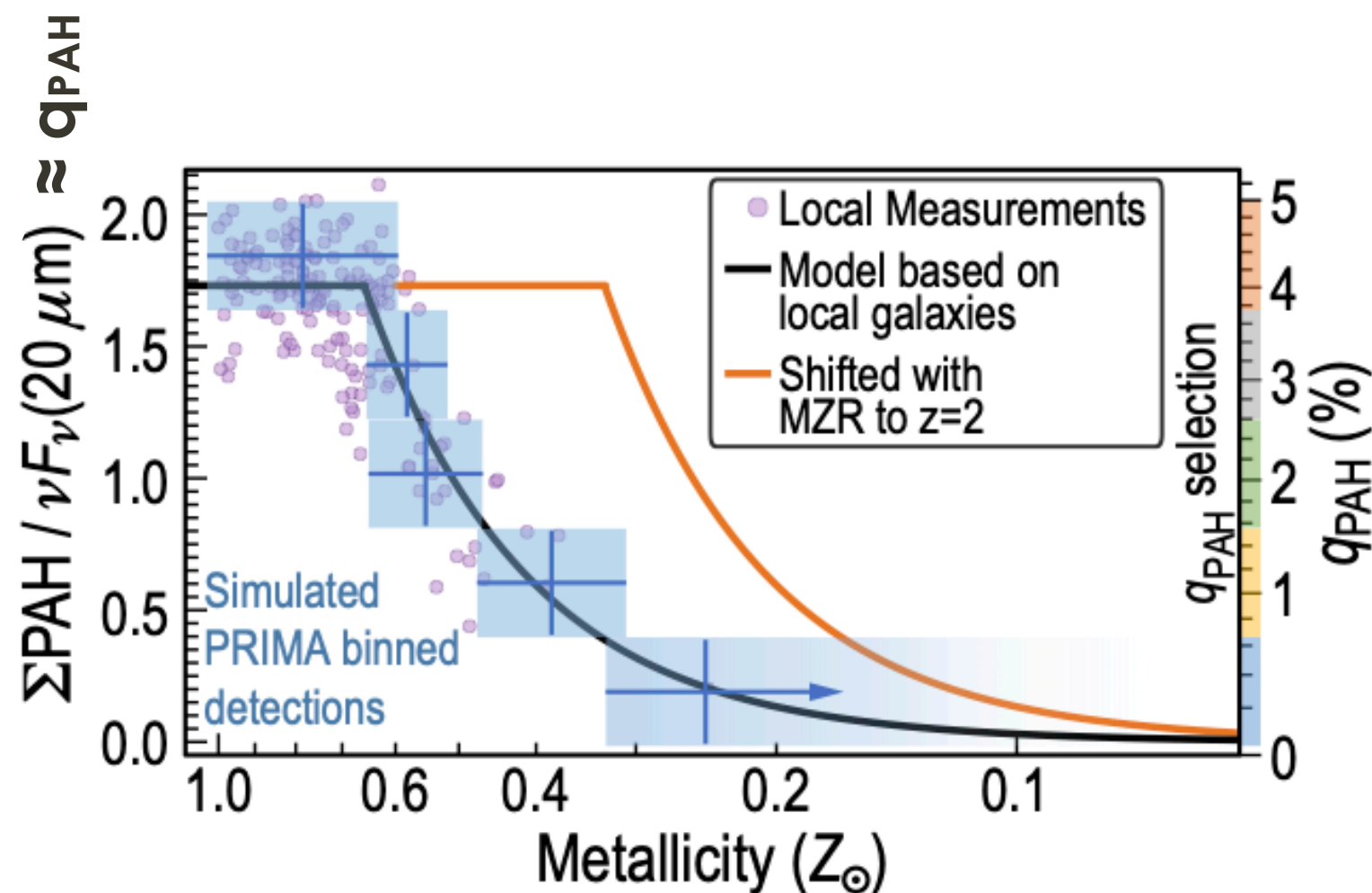
Far-Infrared Metallicity



Chartab et al. 2022



The Rise of Dust and Metals: PAHs and heavy elements since beyond cosmic noon



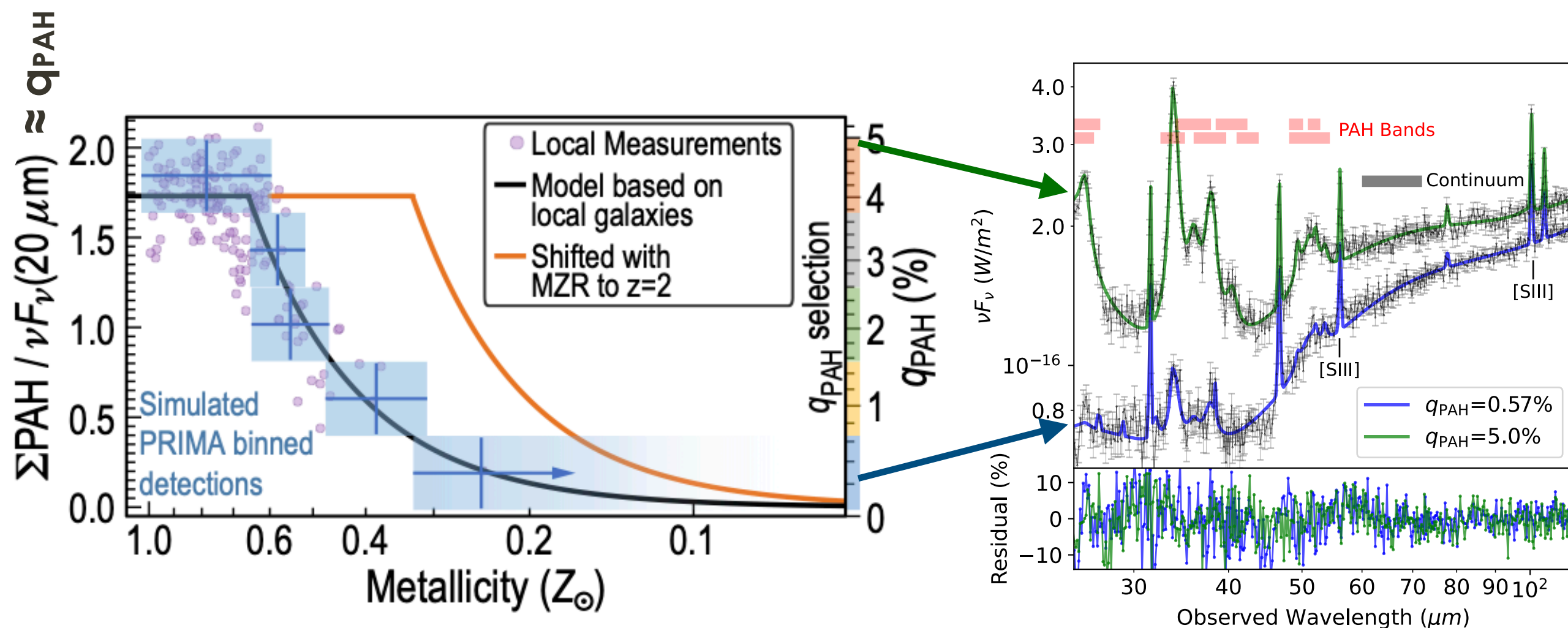
see Whitcomb, JDS, + 2024

PRIMA/FIRESS will observe hundreds of galaxies up to $z=2.5$ to measure:

- Gas-phase **metal abundances** of O and N via [O III], [N III] (aka “O3N3”)
- Direct **PAH abundance** relative to dust (q_{PAH}) from rest-frame PAH emission bands

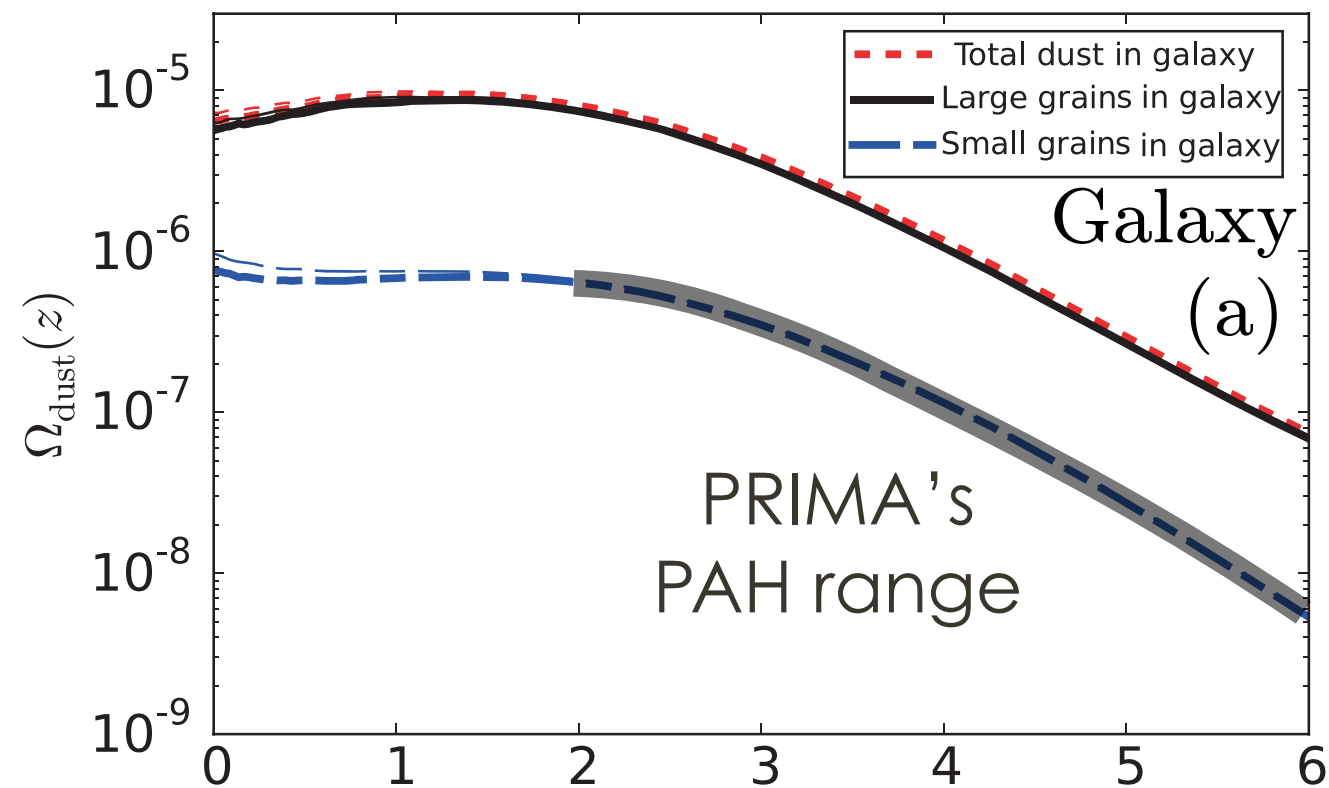


The Rise of Dust and Metals: PAHs and heavy elements since beyond cosmic noon

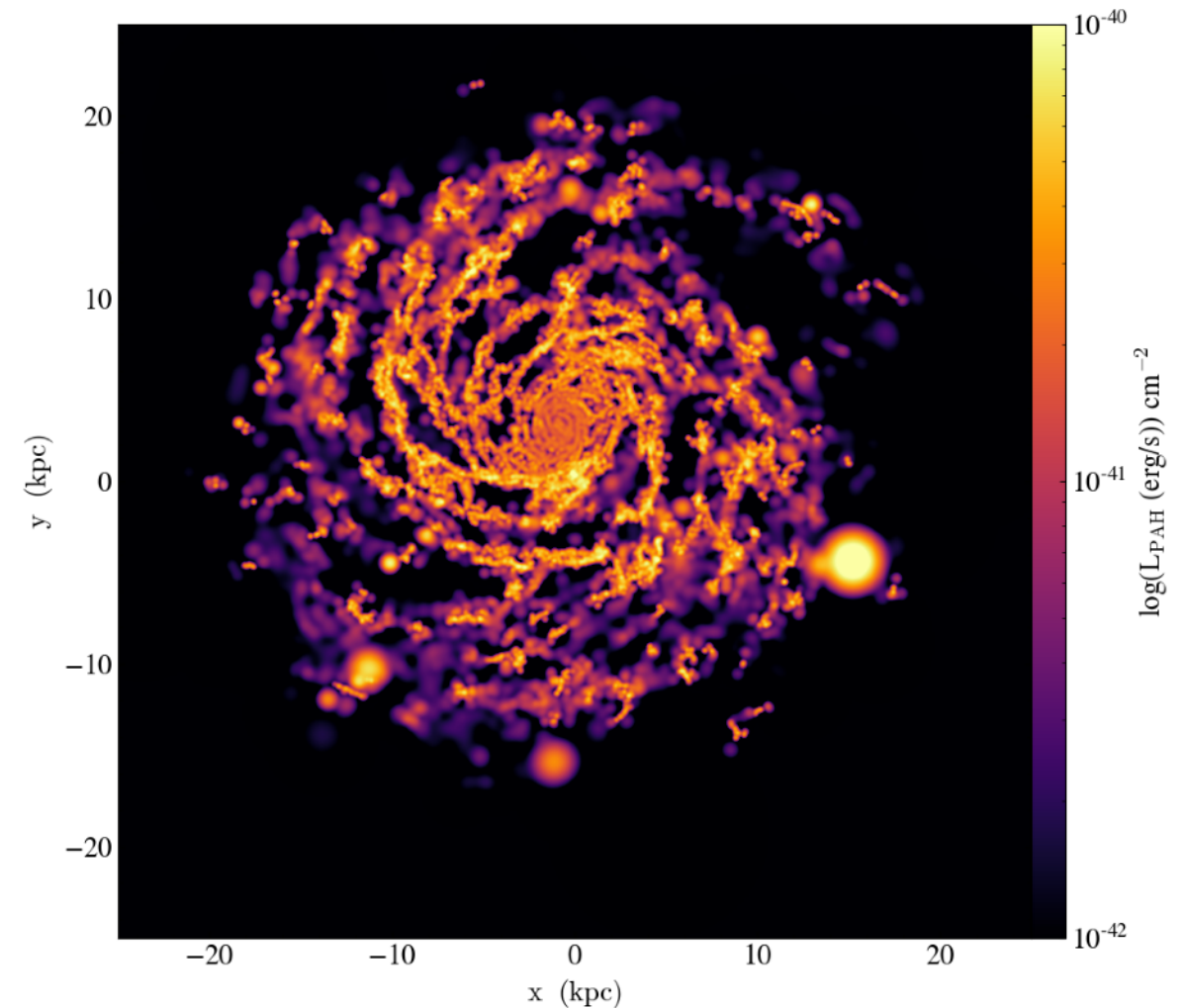


see Whitcomb, JDS, + 2024

PRIMA will trace the **enrichment history of hydrocarbons** in the Universe from early appearance to steady state abundance

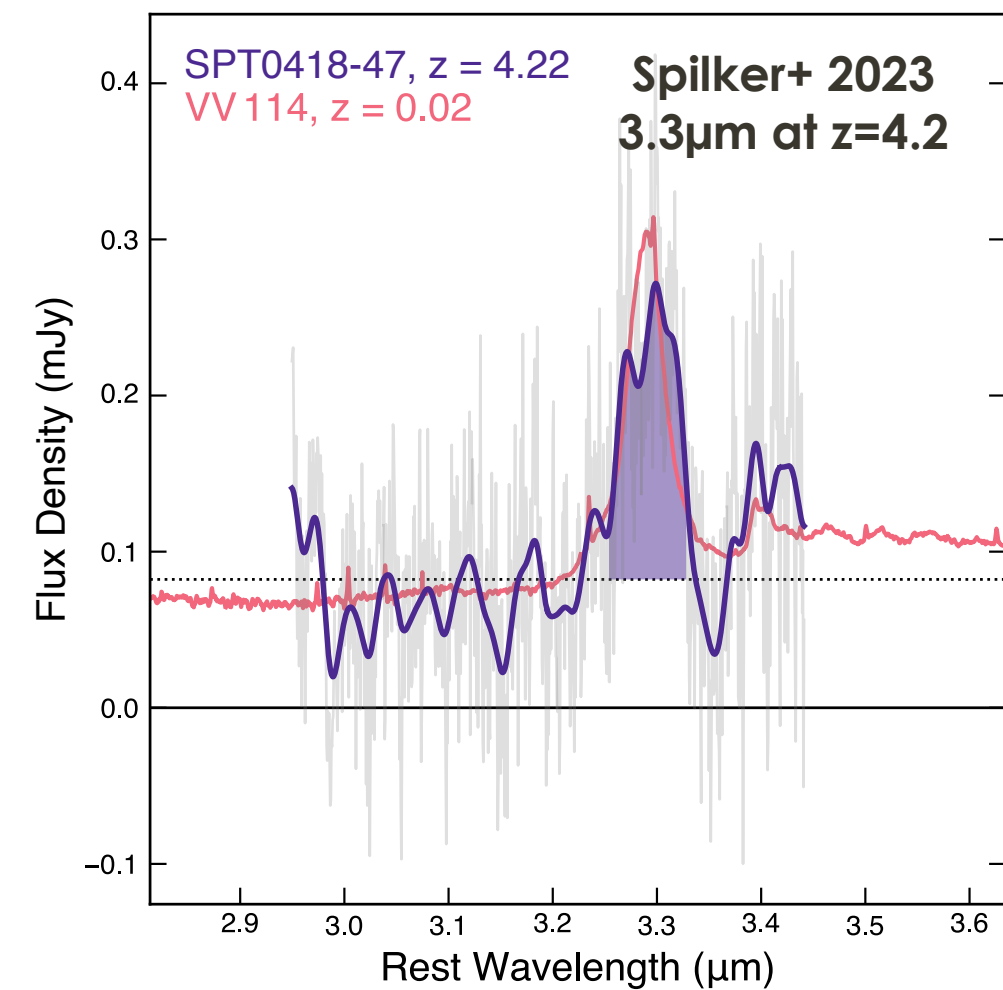


Aoyama+ 2018

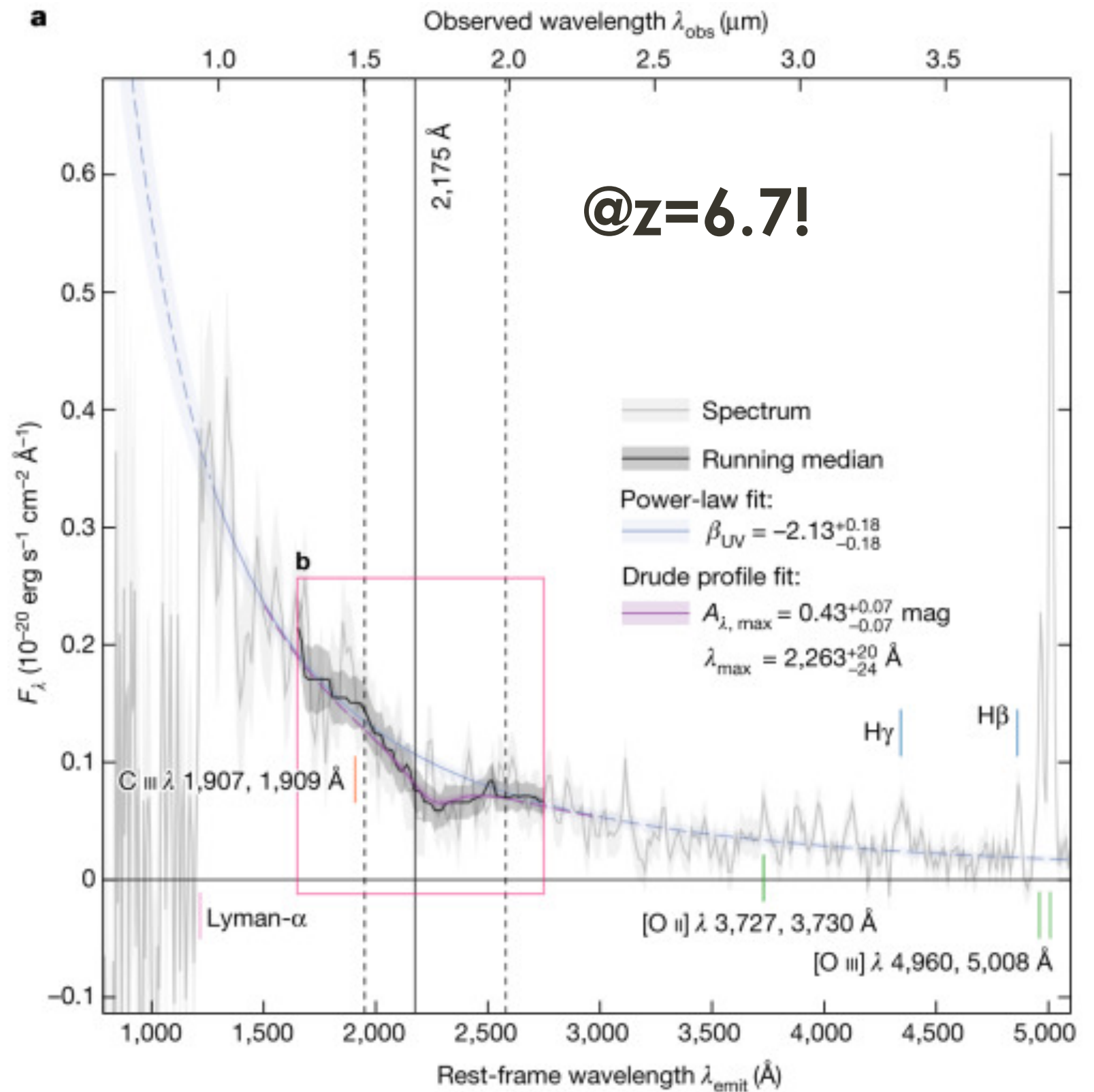


Narayanan, JDS+ 2023

**“First fully self-consistent
PAH emission in
hydrodynamical galaxy
simulations.”**



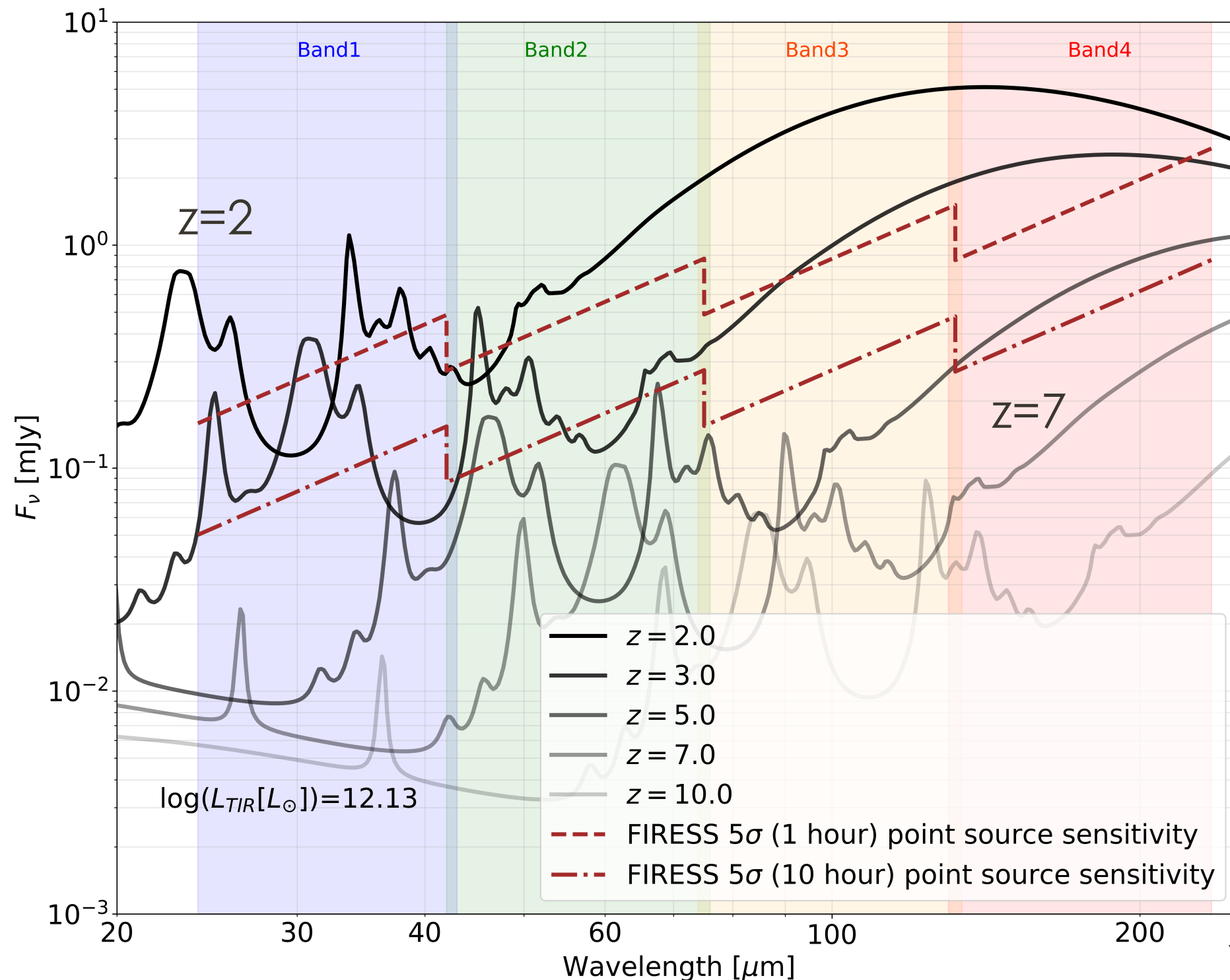
The Rise of Dust in the First Few Gyr



Wistok+ 2023

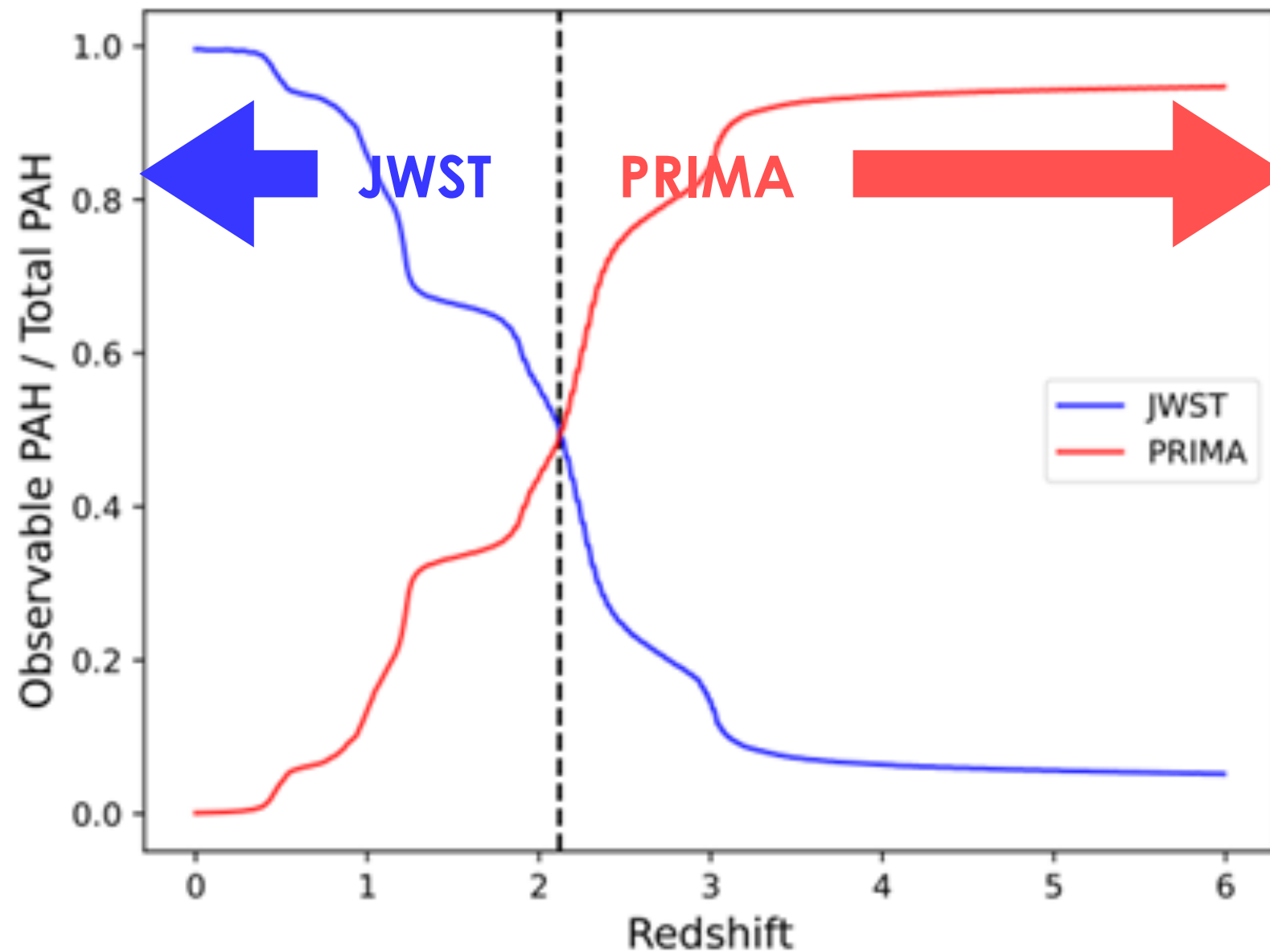
The “P” in PRIMA is for PAH†

†not actually

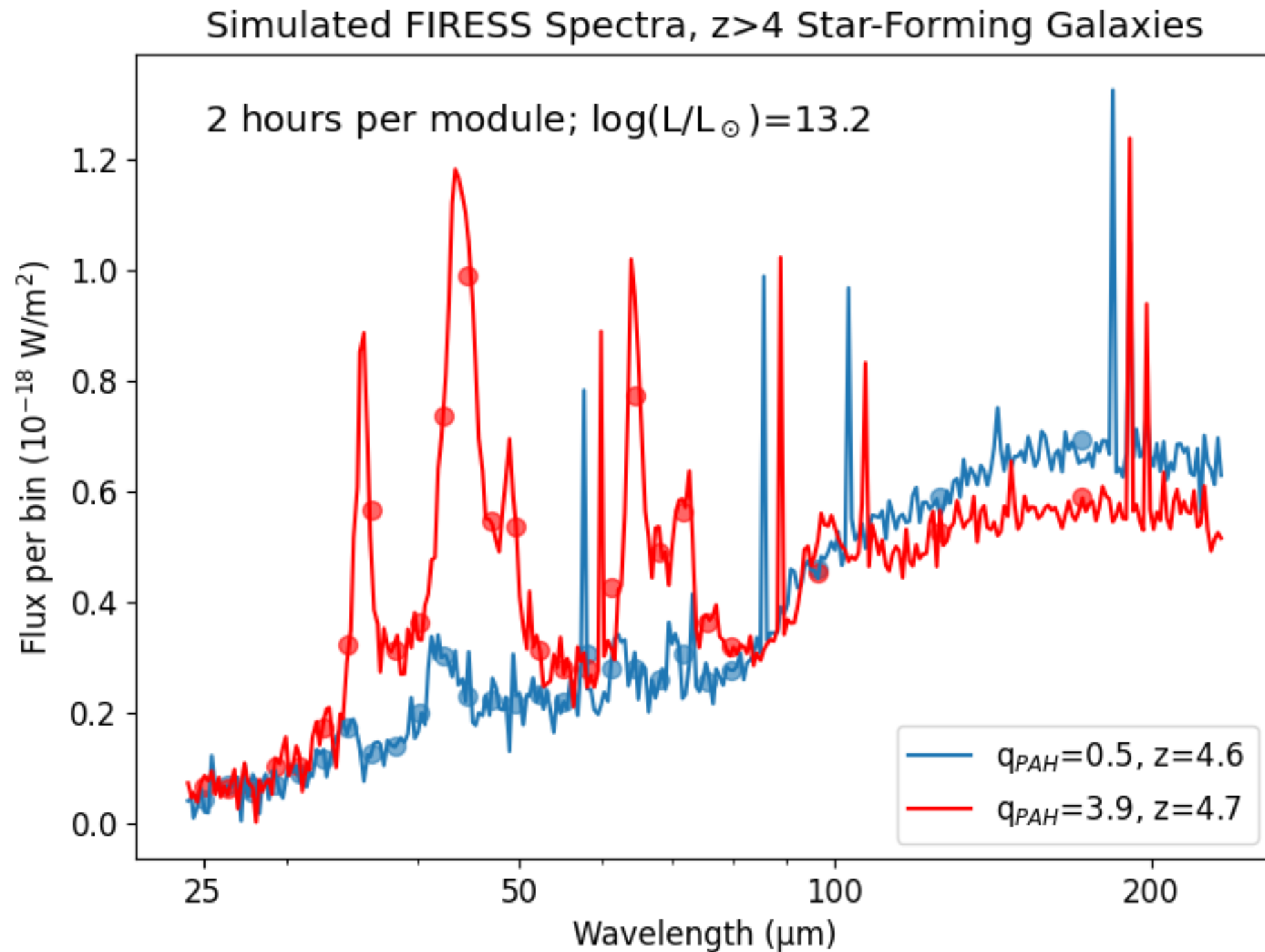


PRIMA will be a high-z PAH machine

Fraction of PAH power covered



PRIMA will be a high- z PAH machine



Get Involved with PRIMA

- **JATIS PRIMA Special Issue** ([←cite here](#))
released in August
(vol 11, Issue 3)
- PRIMA GO Book, 2nd edition
- What will PRIMA do for you?? **Please fill our survey**

prima.ipac.caltech.edu
@PRIMAprobe on X

- **AAS Special Session**
Wed Jan 7 2-3:30

- Sign up for the PRIMA newsletter

Approximate PRIMA Schedule:

- **T-1yr:** PRIMA + AXIS (X-ray)
selected for concept study
- Step 2 *Proposal Submission:*
December
- Selection Site Visit:
late ~**Spring**
- Probe Selection: ???
- **2031/32 Launch**

